

NASA Contractor Report 191009

1N-37
9100
Army Research Laboratory
Contractor Report ARL-CR-121
58 P

Manual for Automatic Generation of Finite Element Models of Spiral Bevel Gears in Mesh

G.D. Bibel
University of North Dakota
Grand Forks, North Dakota

and

S. Reddy and A. Kumar
University of Akron
Akron, Ohio

(NASA-CR-191009) MANUAL FOR
AUTOMATIC GENERATION OF FINITE
ELEMENT MODELS OF SPIRAL BEVEL
GEARS IN MESH Final Report (North
Dakota Univ.) 58 p

N94-32900

Unclass

April 1994

63/37 0009100

Prepared for
Lewis Research Center
Under Grant NAG3-1476



National Aeronautics and
Space Administration



Manual for Automatic Generation of Finite Element Models of Spiral Bevel Gears in Mesh

G.D. Bibel
University of North Dakota
Grand Forks, North Dakota

and

S. Reddy and A. Kumar
University of Akron
Akron, Ohio

ABSTRACT

The goal of this research is to develop computer programs that generate finite element models suitable for doing 3D contact analysis of faced milled spiral bevel gears in mesh. A pinion tooth and a gear tooth are created and put in mesh.

There are two programs:

1. Points.f
2. Pat.f

Points.f is based on the equation of meshing for spiral bevel gears. It uses machine tool settings to solve for an $N \times M$ mesh of points on the four surfaces; pinion concave and convex, and gear concave and convex. Points.f creates the file POINTS.OUT, an ASCII file containing $N \times M$ points for each surface. (N is the number of node points along the length of the tooth, and M is nodes on the height.)

Pat.f reads POINTS.OUT and creates the file t1.out. T1.out is a series of PATRAN input commands. In addition to the mesh density on the tooth face, additional user specified variables are the number of finite elements through the thickness, and the number of finite elements along the tooth full fillet. A full fillet is assumed to exist for both the pinion and gear.

This report is based on the theory presented in Army Research Laboratory Report ARL-TR-158 "Contact Stress Analysis of Spiral Bevel Gears Using Nonlinear Finite Element Static Analysis" by G.D. Bibel, A. Kumar and S. Reddy; and AVSCOM Technical Report 91-C-020 "A Method for Determining Spiral-Bevel Gear Tooth Geometry for Finite Element Analysis" by R. F. Handschuh and F. L. Litvin.

TABLE OF CONTENTS

Summary	1
Procedure	2
Numerical Example (Summary)	3
Input Data: Points.f.	4
Input Data: Pat.f.	7
Output from Points.f.	9
Output from Pat.f.	12
Typical FE mesh	23
Appendix I: Points.f, program listing	25
Points.f Flowchart	34
Appendix II: Pat.f, program listing	37
Pat.f Flowchart	50

SUMMARY

The goal of this research is to develop computer programs that generate finite element models suitable for doing 3D contact analysis of faced milled spiral bevel gears in mesh. A pinion tooth and a gear tooth are created and put in mesh.

There are two programs:

1. Points.f
2. Pat.f

Points.f is based on the equation of meshing for spiral bevel gears. It uses machine tool settings to solve for an $N \times M$ mesh of points on the four surfaces; pinion concave and convex, and gear concave and convex. Points.f creates the file POINTS.OUT, an ASCII file containing $N \times M$ points for each surface. (N is the number of node points along the length of the tooth, and M is nodes on the height.)

NOTE: For Unix based systems, the program titles are case sensitive. All titles are lower case except POINTS.OUT.

Pat.f reads POINTS.OUT and creates the file t1.out. T1.out is a series of PATRAN input commands. In addition to the mesh density on the tooth face, additional user specified variables are the number of finite elements through the thickness, and the number of finite elements along the tooth full fillet. A full fillet is assumed to exist for both the pinion and gear.

This report is based on the theory presented in Army Research Laboratory Report ARL-TR-158 "Contact Stress Analysis of Spiral Bevel Gears Using Nonlinear Finite Element Static Analysis" by G.D. Bibel, A. Kumar and S. Reddy; and AVSCOM Technical Report 91-C-020 "A Method for Determining Spiral-Bevel Gear Tooth Geometry for Finite Element Analysis" by R. F. Handschuh and F. L. Litvin.

The following topics are covered in this report:

1. A description of the detailed procedure for generating a finite element model.
2. Instructions for inserting the data.
3. A numerical example of input and output.
4. A listing of the programs.
5. Sample plots.

Finite element analysis of spiral bevel gears can be used to determine contact stresses, bending stresses, stiffness for dynamic analysis, load sharing, contact area, and thermal gradients.

PROCEDURE

1. Prepare the input data for points.f (described elsewhere in this report) for the pinion.
2. Compile and execute points.f
3. During the execution of points.f, the user is prompted for the desired N x M mesh.
4. Execution of points.f creates the file POINTS.OUT. This file will contain N x M points on the pinion concave surface and N x M points on the pinion convex surface. (2 x N x M total points)
5. Prepare the input data for model.f (described elsewhere in this report) for the pinion.
6. Compile and execute model.f.
7. During the execution of model.f, the user is prompted for the desired N x M mesh. These values must be the same used in step 3 above. The user is also prompted for the number of finite elements through the tooth thickness (this must be an even number), and the number of finite elements along the length of 1/2 of the full fillet. Trial and error may be required to obtain finite elements with appropriate aspect ratios.
8. Execution of model.f creates t1.out. This file is suitable for direct input into PATRAN ver 2.5.

NOTE: An 8 x 6 mesh is suggested as a practice mesh. Accuracy is affected with coarser meshes. (The increment is too large for the numerical solution)

NUMERICAL EXAMPLE (SUMMARY)

A 8 x 6 mesh with 4 elements through the tooth thickness and 4 elements in the fillet region will be used as an example.

1. The input data is as shown in the section INPUT DATA: POINTS.F
2. Attachment 1 shows the output from points.f (i. e. the file POINTS.OUT). This file is the X, Y, and Z coordinates of the N x M mesh of points on the four surfaces.
3. The input data from the next step is as shown in the section INPUT DATA: PAT.F
4. Attachment 2 shows the output from Pat.f (i. e. the file t1.out.
5. Attachment 3 shows a typical PATRAN plot after reading t1.out.

INPUT DATA: Points.f

The input data for Points.f is as shown below. (The input data occurs inside of points.f) Each input variable is self explanatory or explained in detail in the reference reports.

The initial guess is very sensitive. The solution technique may converge on another surface if the initial guess is too far from the correct solution.

```

C
C
C
C
C
C-----
C-----
C      DESCRIPTION OF INPUT DATA
C-----
C
C      1) RADIUS OF CUTTER, INCHES          (R)
C      2) CRADLE ANGLE, DEGREES            (Q)
C      3) BLADE ANGLE, DEGREES             (PSI)
C      4) CRADLE TO CUTTER DISTANCE, INCHES (S)
C      5) RATIO OF ROLL                    (MCW)
C      6) MACHINE OFFSET, INCHES           (EM)
C      7) VECTOR SUM, INCHES               (LM)
C      8) DEDENDUM ANGLE, DEGREES           (DEDEN)
C      9) PITCH ANGLE, DEGREES             (MU)
C     10) ADDENDUM ANGLE, DEGREES           (ADDAN)
C     11) CLEARANCE, INCHES                (CL)
C     12) MEAN CONE DISTANCE, INCHES       (RL)
C     13) FACE WIDTH, INCHES               (FW)
C     14) INITIAL GUESS FOR SURFACE COORDINATE U ( U(1) )
C     15) INITIAL GUESS FOR SURFACE COORDINATE THETA ( THETA(1) )
C     16) INITIAL GUESS FOR ANGLE OF CRADLE, DEGREES ( PHIC(1) )
C-----
C      INSERT CONCAVE SIDE OF PINION DATA BELOW
C-----
C
C      R      = 2.96562137806
C      Q      = 63.9420304635 * PI/180.0
C      PSI    = 161.954330248 * PI/180.0
C      S      = 2.94780202969
C      MCW    = 0.30838512709

```



```

      EM      = 0.154575896
      LM      = 0.0384999977874
      DEDEN   = 1.56666666 * pi/180
      MU      = 18.4333333 * pi/180
      ADDAN   = 3.8833334 * pi/180
      CL      = 0.03
      RL      = 3.191
      FW      = 1.0
      U(1)    = 9.59703
      THETA(1) = 126.83544 * PI/180.0
      PHIC(1) = -0.85813 * PI/180.0
C
      ELSEIF (INT .EQ. 2) THEN
C-----
C      INSERT CONVEX SIDE OF PINION DATA BELOW
C-----
C
      R      = 3.071306157
      Q      = 53.9259945467 * PI/180.0
      PSI    = 24.337423854 * PI/180.0
      S      = 2.80104946
      MCW    = 0.3220428536
      EM     = -0.17426159493
      LM     = -0.0518138227
      DEDEN  = 1.56666666 * pi/180
      MU     = 18.4333333 * pi/180
      ADDAN  = 3.8833334 * pi/180
      CL     = 0.03
      RL     = 3.191
      FW     = 1.0
      U(1)   = 7.42534
      THETA(1) = 124.43689 * PI/180.0
      PHIC(1) = -11.38663 * PI/180.0
C
      ELSEIF (INT .EQ. 3) THEN
C-----
C      INSERT CONCAVE SIDE OF GEAR DATA BELOW
C-----
C
      R      = 3.0325
      Q      = 59.2342023 * PI/180.0
      PSI    = 158.0 * PI/180.0
      S      = 2.85995004691
      MCW    = 0.9508646
      EM     = 0.0
      LM     = 0.0
      DEDEN  = 3.883333333 * pi/180
      MU     = 71.5666666 * pi/180
      ADDAN  = 1.5666666 * pi/180
      CL     = 0.0366
      RL     = 3.191
      FW     = 1.0
      U(1)   = 8.12602
      THETA(1) = 233.98994 * PI/180.0
      PHIC(1) = -0.35063 * PI/180.0
C-----
C
C
C
C
C
      ELSE
C
C-----
C      INSERT CONVEX SIDE OF GEAR DATA BELOW
C-----

```

R = 2.9675
 Q = 59.2342023 * PI/180.0
 PSI = 22.0 * PI/180.0
 S = 2.85995004691
 MCW = 0.9508646
 EM = 0.0
 LM = 0.0
 DEDEN = 3.8833333333 * pi/180
 MU = 71.5666666 * pi/180
 ADDAN = 1.5666666 * pi/180
 CL = 0.0366
 RL = 3.191
 FW = 1.0
 U(1) = 7.89156
 THETA(1) = 234.95451 * PI/180.0
 PHIC(1) = -12.3384 * PI/180.0

INPUT DATA: Pat. f.

The input data for Model.f is as shown below. Some of the data is redundant with Points.f The new variables are as follows:

1. "ROTCON". ROTCON is the rotation of each convex surface required to obtain the desired top land thickness.

2. "ROTINT". ROTINT is the rotation of the pinion required to eliminate interference with the gear.

3. "ROGEAR". ROGEAR is the rotation of the gear required to place the gear in mesh with the pinion. For the general case, the gear tooth is rotated $360/(\text{Number of gear teeth}) + 180$ degrees CW about the Z axis (the gear's axis of rotation).

```
-
C
C=====
C          DESCRIPTION OF INPUT DATA FOR PINION
C=====
C
C      1. DEDENDUM, DEGREES                (DEDEN)
C      2. PITCH ANGLE, DEGREES            (MU)
C      3. ROTATION OF CONVEX SURFACE TO
C          CREATE TOP LAND                (ROTCON)
C      4. ROTATION OF PINION TO ELIMINATE
C          INTERFERENCE                  (ROTINT)
C      5. PINION ID, INCHES                (RI)
C      6. CLEARANCE, INCHES                (CL)
C      7. NUMBER OF PINION TEETH          (NTPIN)
C=====
C
C=====
C          INPUT THE PINION DATA BELOW
C=====
C          DEDEN = 1.56666666 * PI/180.0
C          MU    = 18.4333333 * PI/180.0
C          ROTCON = 2.275
C          ROTINT = -3.56
C          RI    = 0.609375
C          CL    = 0.03
C          NTPIN = 12
C=====
```

```

C
C
C
ELSEIF ((INT .EQ. 3).OR.(INT .EQ. 4)) THEN
C
C
C=====
C      DESCRIPTION OF INPUT DATA FOR THE GEAR
C=====
C
C      1. DEDENDUM, DEGREES                      (DEDEN)
C      2. PITCH ANGEL, DEGREES                  (MU)
C      3. ROTATION OF CONVEX SURFACE TO
C          CREATE TOP LAND                      (ROTCON)
C      4. ROTATION OF GEAR TO PUT IN MESH        (ROGEAR)
C      5. CLEARANCE, INCHES ^                   (CL)
C      6. ID OF GEAR BASE                       (R1)
C      7. OD OF GEAR BASE                       (R2)
C      8. NUMBER OF GEAR TEETH                  (NTGE)
C=====
C
C=====
C      INPUT THE GEAR DATA BELOW
C=====
C
C      DEDEN = 3.883333333 * PI/180.0
C      MU    = 71.56666666 * PI/180.0
C      ROTCON = -8.49
C      ROGEAR = 190.0
C      CL    = 0.0366
C      R1    = 2.375
C      R2    = 3.250
C      NTGE  = 36
C=====
C

```

OUTPUT FROM POINTS.F

X	Y	Z
0.7948185893337920	0.1518771876505158	2.565573009266192
0.8343433613077650	0.1745810495998836	2.552471190313917
0.8720324096583479	0.2042199804427480	2.539369371362535
0.9077908578945182	0.2394490290397444	2.526267552535221
0.9414155876464360	0.2795805696115394	2.513165735668416
0.9726798641190831	0.3241375989552031	2.500063936000037
0.8472371339193625	7.6106029221588933E-02	2.702284801203873
0.8913330776440134	9.5839030874127040E-02	2.688392059145086
0.9342070276559395	0.1231797235370555	2.674499317051919
0.9756155352323542	0.1566714188085960	2.660606575085474
1.015268047213935	0.1955944000191652	2.646713837702351
1.052870943839311	0.2394597732991732	2.632821147263364
0.8920544861387928	-8.7977041450044701E-03	2.838996593145300
0.9405003839933272	7.3083519719827627E-03	2.824312928070127
0.9884537411081434	3.1630276922439470E-02	2.809629262838540
1.035498881976111	6.2620579641409435E-02	2.794945597192247
1.081249167998568	9.9539397524525785E-02	2.780261940615036
1.125338129677023	0.1418941391352297	2.765578408798671
0.9279228340072788	-0.1023212288383641	2.975708385187462
0.9804198623141954	-9.0488151985839593E-02	2.960233797221159
1.033263802256655	-6.9914280082028490E-02	2.944759208992080
1.085845886896256	-4.2211242335634668E-02	2.929284618267694
1.137675976466795	-8.1252212097733256E-03	2.913810043739986
1.188306404191815	3.1855424697372125E-02	2.898335812878913
0.9534599334795802	-0.2037951651625605	3.112420178263912
1.009630926058035	-0.1968645393407975	3.096154666768726
1.067089798650322	-0.1807700720952332	3.079889156026669
1.125017872008955	-0.1571554097480132	3.063623637059750
1.182815359830648	-0.1267574497917443	3.047358144908540
1.239934504589937	-9.0054618527663610E-02	3.031093686081570
0.9672556523581568	-0.3123758786108948	3.249131977522822
1.026644599586983	-0.3109539641202601	3.232075536925217
1.088352545835276	-0.3000651176158047	3.215019104897882
1.151339425325948	-0.2813479710083238	3.197962650909841
1.214890364286590	-0.2555128377780433	3.180906240112322
1.278297192284771	-0.2230290530267571	3.163853372103641
0.9678796662918135	-0.4270252087603694	3.385843803228283
1.029951520163903	-0.4316883253646147	3.367996407956596
1.095449239626837	-0.4267184461595268	3.350149057378801
1.163106632451191	-0.4137081339625599	3.332301654167603
1.232086458109564	-0.3933218937462701	3.314454332645862
1.301293568935084	-0.3660335888044650	3.296621207705554
0.9538905193238456	-0.5464866609459378	3.522555720376076
1.018031477753651	-0.5577745718372567	3.503917280198983
1.086763175986946	-0.5594158588267257	3.485279016743563
1.158596913336253	-0.5529133643964257	3.466640634659134
1.232554428724539	-0.5388625992810234	3.448002511532153
1.306217203742137	-0.5177479993723693	3.429430372498238
0.7093463178422439	0.3893983454546772	2.565573009266191
0.7570852600711056	0.3917005187907718	2.552471190313766
0.8073029755824992	0.3878249981807325	2.539369371359211
0.8593909679113807	0.3779778338261695	2.526267552392368
0.9128138134481132	0.3622148457047225	2.513165733397398
0.9670614194895887	0.3405352495955354	2.500063914362740
0.7805547654008799	0.3381377633245926	2.702284801203850
0.8313192150683369	0.3355117554273983	2.688392059127966
0.8840811061706690	0.3260622820926806	2.674499317054876
0.9382129090097685	0.3100453874934890	2.660606574980783
0.9931445219848133	0.2875595701230784	2.646713832903523
1.048324166687691	0.2586450939788132	2.632821090805444
0.8483132970638206	0.2760491911215923	2.838996593141508
0.9015956233205106	0.2678053743188284	2.824312927885464
0.9562796868411379	0.2521317789571000	2.809629262692835
1.011723722807169	0.2293346362776858	2.794945597542682
1.067325789653079	0.1995595783460700	2.780261932355890
1.122494542284766	0.1628943693243237	2.765578267158041

0.9112000448284689	0.2030391581389535	2.975708385079163
0.9663724749316263	0.1885085186004414	2.960233796271262
1.022236225128360	0.1659976000986125	2.944759207797051
1.078139321839011	0.1358626773835785	2.929284619894748
1.133450935693196	9.8300989821880069E-02	2.913810031777249
1.187542779161388	5.3454488313127157E-02	2.898335443486139
0.9676895991379796	0.1191435063835695	3.112420177016817
1.023995422930553	9.7691650985565203E-02	3.096154663323241
1.080168552957352	6.7782050056511611E-02	3.079889150748298
1.135549961729417	2.9820889650890691E-02	3.063623641171534
1.189482972857256	-1.5938341746537521E-02	3.047358130942706
1.241305512978413	-6.9292504478944305E-02	3.031092619792399
1.016149494629492	2.4546941529382415E-02	3.249131968954469
1.072693870906420	-4.4094230428219916E-03	3.232075526708658
1.128170570501692	-4.2209828439173868E-02	3.215019087512731
1.181915774012974	-8.8397895323604203E-02	3.197962659109970
1.233250099226129	-0.1426588841462646	3.180906229149712
1.281481427875818	-0.2047210348378159	3.163849795972270
1.054836149594651	-8.0393756502517454E-02	3.385843760892120
1.110576450723173	-0.1173673033750138	3.367996381370604
1.164207315546032	-0.1634608596042426	3.350149009219072
1.215061572522443	-0.2181667004477261	3.332301668710605
1.262440437691158	-0.2811032336663852	3.314454324809642
1.305626160434559	-0.3519220612269351	3.296606971745099
1.081890093168536	-0.1951217417487592	3.522555552829777
1.135625698876967	-0.2405311921112059	3.503917217031341
1.186109140444834	-0.2952059400453120	3.485278897558544
1.232670689693987	-0.3585843827438959	3.466640659723548
1.274595758431425	-0.4302115809299476	3.448002414715995
1.311146184992092	-0.5096536842811183	3.429364146542768
2.474433967420987	-0.3395653327372070	0.9856358798469023
2.487839996829133	-0.3593061900500794	0.9465879479135923
2.500980732115327	-0.3799719362136913	0.9075400160259967
2.513847962185435	-0.4014972153625989	0.8684920851879474
2.526433333215689	-0.4238257450684864	0.8294441631803695
2.538728501263516	-0.4469082097766504	0.7903962834276070
2.615744367457404	-0.2713527297527838	1.039882343666109
2.630668874615893	-0.2921776971646133	0.9983126342013517
2.645336856855221	-0.3140021877370152	0.9567429270473953
2.659736900244837	-0.3367554455147062	0.9151732405016411
2.673857752554951	-0.3603767778219593	0.8736036480711737
2.687688379068866	-0.3848131384418187	0.8320343503411255
2.755122082966633	-0.1939252488334882	1.094128807487018
2.771646356120490	-0.2158264544757134	1.050037320781535
2.787926437149529	-0.2388005015425003	1.005945850025553
2.803947251406170	-0.2627715238015491	0.9618544915078790
2.819694200468521	-0.2876746263983043	0.9177635422435383
2.835153088849297	-0.3134531506865259	0.8736736400533243
2.892115805626759	-0.1070309492253978	1.148375271344924
2.910326750723583	-0.1300043557812005	1.101762007915943
2.928309186669705	-0.1541221288023844	1.055148803591732
2.946043871332245	-0.1793036410217184	1.008535978909207
2.963512305696952	-0.2054800085262900	0.9619243699325180
2.980696572015054	-0.2325910821084665	0.9153154443440815
3.026234802111897	-1.0397603116659048E-02	1.202621735548316
3.046226387571472	-3.4443711328922432E-02	1.153486695724431
3.066008199637873	-5.9703409974563026E-02	1.104351817871708
3.085556228980730	-8.6091707633022540E-02	1.055217942501711
3.104847356582463	-0.1135359377283138	1.006086988192335
3.123859380461631	-0.1419726571295392	0.9569616304362697
3.156942158964726	9.6270882267980528E-02	1.256868201705318
3.178817192398615	7.1146146344736038E-02	1.205211384146218
3.200503834343097	4.4741446463306910E-02	1.153554939872925
3.221972538278004	1.7145708246413704E-02	1.101900776270329
3.243194610216827	-1.1564815230486136E-02	1.050252743854398
3.264143329575414	-4.1323831199262528E-02	0.9986146558233269

3.283646305240354	0.2132989412203852	1.311114675992770
3.307518658058060	0.1870830974730224	1.256936072960456
3.331226092948566	0.1595243725147912	1.202758242897250
3.354732453389843	0.1307151794108270	1.148585121565755
3.378002211439905	0.1007351583096741	1.094423714581283
3.401005110789191	6.9652404241723697E-02	1.040277353579933
3.405690273410178	0.3410450079877778	1.365361177977477
3.431687717020426	0.3137175697464407	1.308660761835998
3.457545044455680	0.2849884724816092	1.251961842372733
3.483217889568247	0.2549531672766858	1.195272024233893
3.508662303297751	0.2236944341848668	1.138603073146720
3.533848840376255	0.1912798603623096	1.081952125201376
2.487328996883535	-0.2265447761173172	0.9856358798469033
2.504812553042866	-0.2106249324068905	0.9465879479128150
2.522236712927098	-0.1939207541553278	0.9075400159307193
2.539588928875214	-0.1764076751718493	0.8684920834049786
2.556855251703354	-0.1580661669201349	0.8294441489352412
2.574020473993094	-0.1388819032188771	0.7903962112604109
2.625150758261012	-0.1559948596305243	1.039882343666084
2.643236496908251	-0.1381569984025237	0.9983126341387127
2.661226646330261	-0.1194872621944678	0.9567429246234905
2.679106798755714	-9.9957306928012634E-02	0.9151732151109059
2.696861137105945	-7.9543963548449170E-02	0.8736035055753604
2.714472579493550	-5.8229565504748226E-02	0.8320337957402701
2.760887257218101	-7.6198734391658362E-02	1.094128807485250
2.779466509414771	-5.6307253677417623E-02	1.050037319991277
2.797909320045199	-3.5538740415832492E-02	1.005945831744241
2.816199124496761	-1.3861014156704154E-02	0.9618543448409637
2.834317939922617	8.7529198603615299E-03	0.9177628586525584
2.852246515854574	3.2324360398793938E-02	0.8736713719399361
2.894065956053995	1.3103412573647332E-02	1.148375271304306
2.913016385829245	3.5191943129389446E-02	1.101762003463058
2.931784666433014	5.8200237162429946E-02	1.055148723338887
2.950351750461571	8.2164289773184240E-02	1.008535449229927
2.968697149878801	0.1071150365619262	0.9619221908432191
2.986799102129386	0.1330776555556383	0.9153089376521233
3.024172263795945	0.1121931743753137	1.202621735122491
3.043355635337684	0.1366311709230543	1.153486678790011
3.062306015845269	0.1620292643340986	1.104351548799287
3.081001521818567	0.1884271541347537	1.055216417563395
3.099418775000900	0.2158597377906348	1.0060813714599733
3.117533104008592	0.2443562555318990	0.9569463901021713
3.150641786577461	0.2213780095229714	1.256868198935295
3.169901202815439	0.2483283103564045	1.205211332798929
3.188871257383812	0.2762767736890748	1.153554174173141
3.207526851434866	0.3052666000315338	1.101896921856651
3.225841277669069	0.3353365347774662	1.050239962537327
3.243786499313236	0.3665199653141347	0.9985833243463247
3.272850598337732	0.3409963653901853	1.311114662721890
3.292007036268992	0.3706340385418412	1.256935938473254
3.310811656226333	0.4013059488337771	1.202756289922346
3.329235738826148	0.4330585061056649	1.148576146108771
3.347248740903902	0.4659339811534609	1.094396800991818
3.364818733544274	0.4999698305087152	1.040218589172536
3.390102864455341	0.4714241905482122	1.365361126402474
3.408950759800238	0.5039388434524499	1.308660443733778
3.427377505405820	0.5375223179436728	1.251957231553233
3.445350326286120	0.5722238817764125	1.195252233992485
3.462834246922116	0.6080886634937985	1.138549123343161
3.479792835690703	0.6451578176214294	1.081849345122198

Output from Pat. f.

```

SET,LABEL,OFF
VI
1
120,0,120
GRID, 1,, 0.802715/ 0.102231/ 2.565573
GRID, 2,, 0.843574/ 0.122437/ 2.552471
GRID, 3,, 0.883030/ 0.149678/ 2.539369
GRID, 4,, 0.920907/ 0.182619/ 2.526268
GRID, 5,, 0.956959/ 0.220585/ 2.513166
GRID, 6,, 0.990930/ 0.263115/ 2.500064
GRID, 7,, 0.850328/ 0.023351/ 2.702285
GRID, 8,, 0.895564/ 0.040308/ 2.688392
GRID, 9,, 0.940053/ 0.064934/ 2.674499
GRID, 10,, 0.983461/ 0.095789/ 2.660607
GRID, 11,, 1.025454/ 0.132175/ 2.646714
GRID, 12,, 1.065708/ 0.173621/ 2.632821
GRID, 13,, 0.889787/ -0.064172/ 2.838997
GRID, 14,, 0.939139/ -0.051105/ 2.824313
GRID, 15,, 0.988510/ -0.029808/ 2.809629
GRID, 16,, 1.037389/ -0.001798/ 2.794946
GRID, 17,, 1.085343/ 0.032209/ 2.780262
GRID, 18,, 1.131977/ 0.071744/ 2.765578
GRID, 19,, 0.919779/ -0.159742/ 2.975708
GRID, 20,, 0.972909/ -0.151191/ 2.960234
GRID, 21,, 1.026929/ -0.133939/ 2.944759
GRID, 22,, 1.081129/ -0.109554/ 2.929285
GRID, 23,, 1.134976/ -0.078752/ 2.913810
GRID, 24,, 1.187991/ -0.041992/ 2.898336
GRID, 25,, 0.938966/ -0.262606/ 3.112420
GRID, 26,, 0.995459/ -0.259176/ 3.096155
GRID, 27,, 1.053806/ -0.246681/ 3.079889
GRID, 28,, 1.113089/ -0.226709/ 3.063624
GRID, 29,, 1.172662/ -0.199958/ 3.047358
GRID, 30,, 1.231950/ -0.166873/ 3.031094
GRID, 31,, 0.945993/ -0.371834/ 3.249132
GRID, 32,, 1.005355/ -0.374102/ 3.232076
GRID, 33,, 1.067620/ -0.367066/ 3.215019
GRID, 34,, 1.131648/ -0.352296/ 3.197963
GRID, 35,, 1.196680/ -0.330457/ 3.180906
GRID, 36,, 1.261982/ -0.301973/ 3.163853
GRID, 37,, 0.939496/ -0.486300/ 3.385844
GRID, 38,, 1.001159/ -0.494809/ 3.367996
GRID, 39,, 1.066839/ -0.493916/ 3.350149
GRID, 40,, 1.135174/ -0.485131/ 3.332302
GRID, 41,, 1.205286/ -0.469068/ 3.314454
GRID, 42,, 1.276054/ -0.446129/ 3.296621
GRID, 43,, 0.918116/ -0.604663/ 3.522556
GRID, 44,, 0.981433/ -0.619912/ 3.503917
GRID, 45,, 1.049930/ -0.625818/ 3.485279
GRID, 46,, 1.122029/ -0.623788/ 3.466641
GRID, 47,, 1.196716/ -0.614357/ 3.448003
GRID, 48,, 1.271548/ -0.597857/ 3.429430
GRID, 49,, 0.717900/ 0.373393/ 2.565573
GRID, 50,, 0.765679/ 0.374624/ 2.552471
GRID, 51,, 0.815797/ 0.369623/ 2.539369
GRID, 52,, 0.867651/ 0.358610/ 2.526268
GRID, 53,, 0.920707/ 0.341653/ 2.513166
GRID, 54,, 0.974455/ 0.318763/ 2.500064
GRID, 55,, 0.787941/ 0.320548/ 2.702285
GRID, 56,, 0.838634/ 0.316785/ 2.688392
GRID, 57,, 0.891171/ 0.306154/ 2.674499
GRID, 58,, 0.944930/ 0.288927/ 2.660607
GRID, 59,, 0.999343/ 0.265215/ 2.646714
GRID, 60,, 1.053861/ 0.235071/ 2.632821
GRID, 61,, 0.854291/ 0.256956/ 2.838997
GRID, 62,, 0.907375/ 0.247519/ 2.824313

```


GRID,	63,,	0.961693/	0.230623/	2.809629
GRID,	64,,	1.016612/	0.206588/	2.794946
GRID,	65,,	1.071533/	0.175574/	2.780262
GRID,	66,,	1.125865/	0.137681/	2.765578
GRID,	67,,	0.915524/	0.182554/	2.975708
GRID,	68,,	0.970357/	0.166790/	2.960234
GRID,	69,,	1.025702/	0.143032/	2.944759
GRID,	70,,	1.080915/	0.111651/	2.929285
GRID,	71,,	1.135370/	0.072858/	2.913810
GRID,	72,,	1.188443/	0.026810/	2.898335
GRID,	73,,	0.970118/	0.097413/	3.112420
GRID,	74,,	1.025929/	0.074703/	3.096155
GRID,	75,,	1.081417/	0.043542/	3.079889
GRID,	76,,	1.135933/	0.004348/	3.063624
GRID,	77,,	1.188826/	-0.042609/	3.047358
GRID,	78,,	1.239439/	-0.097112/	3.031093
GRID,	79,,	1.016444/	0.001753/	3.249132
GRID,	80,,	1.072325/	-0.028464/	3.232076
GRID,	81,,	1.126940/	-0.067499/	3.215019
GRID,	82,,	1.179636/	-0.114881/	3.197963
GRID,	83,,	1.229741/	-0.170279/	3.180906
GRID,	84,,	1.276568/	-0.233408/	3.163850
GRID,	85,,	1.052768/	-0.104029/	3.385844
GRID,	86,,	1.107665/	-0.142243/	3.367996
GRID,	87,,	1.160249/	-0.189528/	3.350149
GRID,	88,,	1.209863/	-0.245360/	3.332302
GRID,	89,,	1.255819/	-0.309344/	3.314454
GRID,	90,,	1.297406/	-0.381113/	3.296607
GRID,	91,,	1.077242/	-0.219335/	3.522556
GRID,	92,,	1.129946/	-0.265938/	3.503917
GRID,	93,,	1.179191/	-0.321731/	3.485279
GRID,	94,,	1.224319/	-0.386138/	3.466641
GRID,	95,,	1.264627/	-0.458687/	3.448002
GRID,	96,,	1.299387/	-0.538929/	3.429364
GRID,	97,,	-2.495807/	-0.095275/	0.985636
GRID,	98,,	-2.512437/	-0.078162/	0.946588
GRID,	99,,	-2.528967/	-0.060092/	0.907540
GRID,	100,,	-2.545376/	-0.041128/	0.868492
GRID,	101,,	-2.561648/	-0.021324/	0.829444
GRID,	102,,	-2.577764/	-0.000727/	0.790396
GRID,	103,,	-2.623125/	-0.186989/	1.039882
GRID,	104,,	-2.641439/	-0.169072/	0.998313
GRID,	105,,	-2.659674/	-0.150126/	0.956743
GRID,	106,,	-2.677806/	-0.130219/	0.915173
GRID,	107,,	-2.695815/	-0.109409/	0.873604
GRID,	108,,	-2.713678/	-0.087745/	0.832034
GRID,	109,,	-2.746940/	-0.287443/	1.094129
GRID,	110,,	-2.767017/	-0.268744/	1.050037
GRID,	111,,	-2.787039/	-0.248946/	1.005946
GRID,	112,,	-2.806979/	-0.228121/	0.961854
GRID,	113,,	-2.826811/	-0.206331/	0.917764
GRID,	114,,	-2.846511/	-0.183628/	0.873674
GRID,	115,,	-2.866764/	-0.396806/	1.148375
GRID,	116,,	-2.888687/	-0.377344/	1.101762
GRID,	117,,	-2.910585/	-0.356715/	1.055149
GRID,	118,,	-2.932423/	-0.334996/	1.008536
GRID,	119,,	-2.954171/	-0.312250/	0.961924
GRID,	120,,	-2.975802/	-0.288535/	0.915315
GRID,	121,,	-2.982065/	-0.515261/	1.202622
GRID,	122,,	-3.005928/	-0.495052/	1.153487
GRID,	123,,	-3.029796/	-0.473611/	1.104352
GRID,	124,,	-3.053629/	-0.451018/	1.055218
GRID,	125,,	-3.077393/	-0.427340/	1.006087
GRID,	126,,	-3.101054/	-0.402637/	0.956962
GRID,	127,,	-3.092264/	-0.643006/	1.256868
GRID,	128,,	-3.118169/	-0.622061/	1.205211

GRID, 129,,	-3.144112/	-0.599824/	1.153555
GRID, 130,,	-3.170046/	-0.576375/	1.101901
GRID, 131,,	-3.195931/	-0.551786/	1.050253
GRID, 132,,	-3.221729/	-0.526117/	0.998615
GRID, 133,,	-3.196721/	-0.780258/	1.311115
GRID, 134,,	-3.224783/	-0.758586/	1.256936
GRID, 135,,	-3.252916/	-0.735562/	1.202758
GRID, 136,,	-3.281068/	-0.711273/	1.148585
GRID, 137,,	-3.309190/	-0.685789/	1.094424
GRID, 138,,	-3.337241/	-0.659173/	1.040277
GRID, 139,,	-3.294728/	-0.927256/	1.365361
GRID, 140,,	-3.325076/	-0.904858/	1.308661
GRID, 141,,	-3.355529/	-0.881056/	1.251962
GRID, 142,,	-3.386028/	-0.855935/	1.195272
GRID, 143,,	-3.416514/	-0.829569/	1.138603
GRID, 144,,	-3.446946/	-0.802021/	1.081952
GRID, 145,,	-2.492435/	0.160921/	0.985636
GRID, 146,,	-2.509493/	0.144546/	0.946588
GRID, 147,,	-2.526471/	0.127389/	0.907540
GRID, 148,,	-2.543356/	0.109424/	0.868492
GRID, 149,,	-2.560133/	0.090634/	0.829444
GRID, 150,,	-2.576786/	0.071004/	0.790396
GRID, 151,,	-2.628350/	0.086764/	1.039882
GRID, 152,,	-2.645959/	0.068456/	0.998313
GRID, 153,,	-2.663451/	0.049318/	0.956743
GRID, 154,,	-2.680810/	0.029324/	0.915173
GRID, 155,,	-2.698021/	0.008450/	0.873604
GRID, 156,,	-2.715064/	-0.013321/	0.832034
GRID, 157,,	-2.761936/	0.003419/	1.094129
GRID, 158,,	-2.779985/	-0.016955/	1.050037
GRID, 159,,	-2.797874/	-0.038203/	1.005946
GRID, 160,,	-2.815586/	-0.060355/	0.961854
GRID, 161,,	-2.833103/	-0.083438/	0.917763
GRID, 162,,	-2.850404/	-0.107474/	0.873671
GRID, 163,,	-2.892716/	-0.089362/	1.148375
GRID, 164,,	-2.911077/	-0.111942/	1.101762
GRID, 165,,	-2.929233/	-0.135437/	1.055149
GRID, 166,,	-2.947162/	-0.159882/	1.008535
GRID, 167,,	-2.964844/	-0.185307/	0.961922
GRID, 168,,	-2.982255/	-0.211738/	0.915309
GRID, 169,,	-3.020166/	-0.191846/	1.202622
GRID, 170,,	-3.038698/	-0.216781/	1.153487
GRID, 171,,	-3.056973/	-0.242669/	1.104352
GRID, 172,,	-3.074966/	-0.269551/	1.055216
GRID, 173,,	-3.092654/	-0.297459/	1.006081
GRID, 174,,	-3.110011/	-0.326423/	0.956946
GRID, 175,,	-3.143714/	-0.304325/	1.256868
GRID, 176,,	-3.162257/	-0.331774/	1.205211
GRID, 177,,	-3.180484/	-0.360212/	1.153554
GRID, 178,,	-3.198369/	-0.389684/	1.101897
GRID, 179,,	-3.215884/	-0.420226/	1.050240
GRID, 180,,	-3.233002/	-0.451871/	0.998583
GRID, 181,,	-3.262728/	-0.427123/	1.311115
GRID, 182,,	-3.281097/	-0.457255/	1.256936
GRID, 183,,	-3.299087/	-0.488411/	1.202756
GRID, 184,,	-3.316668/	-0.520639/	1.148576
GRID, 185,,	-3.333808/	-0.553977/	1.094397
GRID, 186,,	-3.350475/	-0.588464/	1.040219
GRID, 187,,	-3.376503/	-0.560595/	1.365361
GRID, 188,,	-3.394487/	-0.593595/	1.308660
GRID, 189,,	-3.412023/	-0.627652/	1.251957
GRID, 190,,	-3.429075/	-0.662815/	1.195252
GRID, 191,,	-3.445608/	-0.699128/	1.138549
GRID, 192,,	-3.461584/	-0.736632/	1.081849
LINE, 1,ST,,	1,	49	
LINE, 9/ 10,BR,.5,	1		

LINE,	2,ST,,	7,	55		
LINE,	11/ 12,BR,.5,	2			
LINE,	3,ST,,	13,	61		
LINE,	13/ 14,BR,.5,	3			
LINE,	4,ST,,	19,	67		
LINE,	15/ 16,BR,.5,	4			
LINE,	5,ST,,	25,	73		
LINE,	17/ 18,BR,.5,	5			
LINE,	6,ST,,	31,	79		
LINE,	19/ 20,BR,.5,	6			
LINE,	7,ST,,	37,	85		
LINE,	21/ 22,BR,.5,	7			
LINE,	8,ST,,	43,	91		
LINE,	23/ 24,BR,.5,	8			
PATCH,	1, QUAD,,	1/	2/	50/	49
PATCH,	2, QUAD,,	2/	3/	51/	50
PATCH,	3, QUAD,,	3/	4/	52/	51
PATCH,	4, QUAD,,	4/	5/	53/	52
PATCH,	5, QUAD,,	5/	6/	54/	53
PATCH,	6, QUAD,,	7/	8/	56/	55
PATCH,	7, QUAD,,	8/	9/	57/	56
PATCH,	8, QUAD,,	9/	10/	58/	57
PATCH,	9, QUAD,,	10/	11/	59/	58
PATCH,	10, QUAD,,	11/	12/	60/	59
PATCH,	11, QUAD,,	13/	14/	62/	61
PATCH,	12, QUAD,,	14/	15/	63/	62
PATCH,	13, QUAD,,	15/	16/	64/	63
PATCH,	14, QUAD,,	16/	17/	65/	64
PATCH,	15, QUAD,,	17/	18/	66/	65
PATCH,	16, QUAD,,	19/	20/	68/	67
PATCH,	17, QUAD,,	20/	21/	69/	68
PATCH,	18, QUAD,,	21/	22/	70/	69
PATCH,	19, QUAD,,	22/	23/	71/	70
PATCH,	20, QUAD,,	23/	24/	72/	71
PATCH,	21, QUAD,,	25/	26/	74/	73
PATCH,	22, QUAD,,	26/	27/	75/	74
PATCH,	23, QUAD,,	27/	28/	76/	75
PATCH,	24, QUAD,,	28/	29/	77/	76
PATCH,	25, QUAD,,	29/	30/	78/	77
PATCH,	26, QUAD,,	31/	32/	80/	79
PATCH,	27, QUAD,,	32/	33/	81/	80
PATCH,	28, QUAD,,	33/	34/	82/	81
PATCH,	29, QUAD,,	34/	35/	83/	82
PATCH,	30, QUAD,,	35/	36/	84/	83
PATCH,	31, QUAD,,	37/	38/	86/	85
PATCH,	32, QUAD,,	38/	39/	87/	86
PATCH,	33, QUAD,,	39/	40/	88/	87
PATCH,	34, QUAD,,	40/	41/	89/	88
PATCH,	35, QUAD,,	41/	42/	90/	89
PATCH,	36, QUAD,,	43/	44/	92/	91
PATCH,	37, QUAD,,	44/	45/	93/	92
PATCH,	38, QUAD,,	45/	46/	94/	93
PATCH,	39, QUAD,,	46/	47/	95/	94
PATCH,	40, QUAD,,	47/	48/	96/	95
HPAT,	1,2P,,	1,	6		
HPAT,	2,2P,,	2,	7		
HPAT,	3,2P,,	3,	8		
HPAT,	4,2P,,	4,	9		
HPAT,	5,2P,,	5,	10		
HPAT,	6,2P,,	6,	11		
HPAT,	7,2P,,	7,	12		
HPAT,	8,2P,,	8,	13		
HPAT,	9,2P,,	9,	14		
HPAT,	10,2P,,	10,	15		
HPAT,	11,2P,,	11,	16		
HPAT,	12,2P,,	12,	17		

HPAT, 13,2P,, 13, 18
 HPAT, 14,2P,, 14, 19
 HPAT, 15,2P,, 15, 20
 HPAT, 16,2P,, 16, 21
 HPAT, 17,2P,, 17, 22
 HPAT, 18,2P,, 18, 23
 HPAT, 19,2P,, 19, 24
 HPAT, 20,2P,, 20, 25
 HPAT, 21,2P,, 21, 26
 HPAT, 22,2P,, 22, 27
 HPAT, 23,2P,, 23, 28
 HPAT, 24,2P,, 24, 29
 HPAT, 25,2P,, 25, 30
 HPAT, 26,2P,, 26, 31
 HPAT, 27,2P,, 27, 32
 HPAT, 28,2P,, 28, 33
 HPAT, 29,2P,, 29, 34
 HPAT, 30,2P,, 30, 35
 HPAT, 31,2P,, 31, 36
 HPAT, 32,2P,, 32, 37
 HPAT, 33,2P,, 33, 38
 HPAT, 34,2P,, 34, 39
 HPAT, 35,2P,, 35, 40
 GRID, 201,, 0.604492/ 0.076986/ 2.565573
 LINE, 25,ARC,5(0)/1/ 20.22185, 201
 GRID, 203,, 0.609145/ 0.016728/ 2.702285
 LINE, 26,ARC,5(0)/1/ 20.56433, 203
 GRID, 205,, 0.607796/ -0.043834/ 2.838997
 LINE, 27,ARC,5(0)/1/ 20.86543, 205
 GRID, 207,, 0.600388/ -0.104272/ 2.975708
 LINE, 28,ARC,5(0)/1/ 21.12931, 207
 GRID, 209,, 0.586856/ -0.164129/ 3.112420
 LINE, 29,ARC,5(0)/1/ 21.35904, 209
 GRID, 211,, 0.567137/ -0.222920/ 3.249132
 LINE, 30,ARC,5(0)/1/ 21.55671, 211
 GRID, 213,, 0.541174/ -0.280122/ 3.385844
 LINE, 31,ARC,5(0)/1/ 21.72357, 213
 GRID, 215,, 0.508920/ -0.335170/ 3.522556
 LINE, 32,ARC,5(0)/1/ 21.85998, 215
 LINE, 33,ARC, 0.80851/ 0.03345/0/ 0.80851/ 0.03345/1.0/ 170.22185, 1
 LINE, 49/ 50,BR,.5, 33
 LINE, 34 ,ARC,0/0/0/0/0/1/ -9.778, 201
 LINE, 81/ 82,BR,.5, 34
 LINE, 65,ST,, 193, 220
 LINE, 97,ST,, 218, 220
 LINE, 105,ST,, 49, 202
 LINE, 113,ST,, 217, 219
 LI, 121,MER,, 25/ 81
 LINE, 35,ARC, 0.84937/-0.04667/0/ 0.84937/-0.04667/1.0/ 170.56433, 7
 LINE, 51/ 52,BR,.5, 35
 LINE, 36 ,ARC,0/0/0/0/0/1/ -9.436, 203
 LINE, 83/ 84,BR,.5, 36
 LINE, 66,ST,, 194, 224
 LINE, 98,ST,, 222, 224
 LINE, 106,ST,, 55, 204
 LINE, 114,ST,, 221, 223
 LI, 122,MER,, 26/ 83
 LINE, 37,ARC, 0.88185/-0.13482/0/ 0.88185/-0.13482/1.0/ 170.86543, 13
 LINE, 53/ 54,BR,.5, 37
 LINE, 38 ,ARC,0/0/0/0/0/1/ -9.135, 205
 LINE, 85/ 86,BR,.5, 38
 LINE, 67,ST,, 195, 228
 LINE, 99,ST,, 226, 228
 LINE, 107,ST,, 61, 206
 LINE, 115,ST,, 225, 227
 LI, 123,MER,, 27/ 85

LINE, 39,ARC, 0.90467/-0.23039/0/ 0.90467/-0.23039/1.0/ 171.12931, 19
 LINE, 55/ 56,BR,.5, 39
 LINE, 40 ,ARC,0/0/0/0/0/1/ -8.871, 207
 LINE, 87/ 88,BR,.5, 40
 LINE, 68,ST,, 196, 232
 LINE, 100,ST,, 230, 232
 LINE, 108,ST,, 67, 208
 LINE, 116,ST,, 229, 231
 LI, 124,MER,, 28/ 87
 LINE, 41,ARC, 0.91651/-0.33260/0/ 0.91651/-0.33260/1.0/ 171.35904, 25
 LINE, 57/ 58,BR,.5, 41
 LINE, 42 ,ARC,0/0/0/0/0/1/ -8.641, 209
 LINE, 89/ 90,BR,.5, 42
 LINE, 69,ST,, 197, 236
 LINE, 101,ST,, 234, 236
 LINE, 109,ST,, 73, 210
 LINE, 117,ST,, 233, 235
 LI, 125,MER,, 29/ 89
 LINE, 43,ARC, 0.91605/-0.44046/0/ 0.91605/-0.44046/1.0/ 171.55671, 31
 LINE, 59/ 60,BR,.5, 43
 LINE, 44 ,ARC,0/0/0/0/0/1/ -8.443, 211
 LINE, 91/ 92,BR,.5, 44
 LINE, 70,ST,, 198, 240
 LINE, 102,ST,, 238, 240
 LINE, 110,ST,, 79, 212
 LINE, 118,ST,, 237, 239
 LI, 126,MER,, 30/ 91
 LINE, 45,ARC, 0.90195/-0.55283/0/ 0.90195/-0.55283/1.0/ 171.72357, 37
 LINE, 61/ 62,BR,.5, 45
 LINE, 46 ,ARC,0/0/0/0/0/1/ -8.276, 213
 LINE, 93/ 94,BR,.5, 46
 LINE, 71,ST,, 199, 244
 LINE, 103,ST,, 242, 244
 LINE, 111,ST,, 85, 214
 LINE, 119,ST,, 241, 243
 LI, 127,MER,, 31/ 93
 LINE, 47,ARC, 0.87288/-0.66830/0/ 0.87288/-0.66830/1.0/ 171.85998, 43
 LINE, 63/ 64,BR,.5, 47
 LINE, 48 ,ARC,0/0/0/0/0/1/ -8.140, 215
 LINE, 95/ 96,BR,.5, 48
 LINE, 72,ST,, 200, 248
 LINE, 104,ST,, 246, 248
 LINE, 112,ST,, 91, 216
 LINE, 120,ST,, 245, 247
 LI, 128,MER,, 32/ 95
 PA, 41,EDGE,, 10/ 105/ 121/ 65
 PA, 49,EDGE,, 9/ 65/ 97/ 49
 PA, 57,EDGE,, 82/ 113/ 50/ 97
 PA, 42,EDGE,, 12/ 106/ 122/ 66
 PA, 50,EDGE,, 11/ 66/ 98/ 51
 PA, 58,EDGE,, 84/ 114/ 52/ 98
 PA, 43,EDGE,, 14/ 107/ 123/ 67
 PA, 51,EDGE,, 13/ 67/ 99/ 53
 PA, 59,EDGE,, 86/ 115/ 54/ 99
 PA, 44,EDGE,, 16/ 108/ 124/ 68
 PA, 52,EDGE,, 15/ 68/ 100/ 55
 PA, 60,EDGE,, 88/ 116/ 56/ 100
 PA, 45,EDGE,, 18/ 109/ 125/ 69
 PA, 53,EDGE,, 17/ 69/ 101/ 57
 PA, 61,EDGE,, 90/ 117/ 58/ 101
 PA, 46,EDGE,, 20/ 110/ 126/ 70
 PA, 54,EDGE,, 19/ 70/ 102/ 59
 PA, 62,EDGE,, 92/ 118/ 60/ 102
 PA, 47,EDGE,, 22/ 111/ 127/ 71
 PA, 55,EDGE,, 21/ 71/ 103/ 61
 PA, 63,EDGE,, 94/ 119/ 62/ 103

```

PA, 48,EDGE,, 24/ 112/ 128/ 72
PA, 56,EDGE,, 23/ 72/ 104/ 63
PA, 64,EDGE,, 96/ 120/ 64/ 104
HPAT, 36 ,2P,, 41, 42
HPAT, 43 ,2P,, 49, 50
HPAT, 50 ,2P,, 57, 58
HPAT, 37 ,2P,, 42, 43
HPAT, 44 ,2P,, 50, 51
HPAT, 51 ,2P,, 58, 59
HPAT, 38 ,2P,, 43, 44
HPAT, 45 ,2P,, 51, 52
HPAT, 52 ,2P,, 59, 60
HPAT, 39 ,2P,, 44, 45
HPAT, 46 ,2P,, 52, 53
HPAT, 53 ,2P,, 60, 61
HPAT, 40 ,2P,, 45, 46
HPAT, 47 ,2P,, 53, 54
HPAT, 54 ,2P,, 61, 62
HPAT, 41 ,2P,, 46, 47
HPAT, 48 ,2P,, 54, 55
HPAT, 55 ,2P,, 62, 63
HPAT, 42 ,2P,, 47, 48
HPAT, 49 ,2P,, 55, 56
HPAT, 56 ,2P,, 63, 64
SET,LINES,0
NAME,PI 1
SET,ACTIVE,NONE
LINE, 129,ST,, 97, 145
LINE,137/138,BR,.5, 129
LINE, 130,ST,, 103, 151
LINE,139/140,BR,.5, 130
LINE, 131,ST,, 109, 157
LINE,141/142,BR,.5, 131
LINE, 132,ST,, 115, 163
LINE,143/144,BR,.5, 132
LINE, 133,ST,, 121, 169
LINE,145/146,BR,.5, 133
LINE, 134,ST,, 127, 175
LINE,147/148,BR,.5, 134
LINE, 135,ST,, 133, 181
LINE,149/150,BR,.5, 135
LINE, 136,ST,, 139, 187
LINE,151/152,BR,.5, 136
PATCH, 65, QUAD,, 97/ 98/ 146/ 145
PATCH, 66, QUAD,, 98/ 99/ 147/ 146
PATCH, 67, QUAD,, 99/ 100/ 148/ 147
PATCH, 68, QUAD,, 100/ 101/ 149/ 148
PATCH, 69, QUAD,, 101/ 102/ 150/ 149
PATCH, 70, QUAD,, 103/ 104/ 152/ 151
PATCH, 71, QUAD,, 104/ 105/ 153/ 152
PATCH, 72, QUAD,, 105/ 106/ 154/ 153
PATCH, 73, QUAD,, 106/ 107/ 155/ 154
PATCH, 74, QUAD,, 107/ 108/ 156/ 155
PATCH, 75, QUAD,, 109/ 110/ 158/ 157
PATCH, 76, QUAD,, 110/ 111/ 159/ 158
PATCH, 77, QUAD,, 111/ 112/ 160/ 159
PATCH, 78, QUAD,, 112/ 113/ 161/ 160
PATCH, 79, QUAD,, 113/ 114/ 162/ 161
PATCH, 80, QUAD,, 115/ 116/ 164/ 163
PATCH, 81, QUAD,, 116/ 117/ 165/ 164
PATCH, 82, QUAD,, 117/ 118/ 166/ 165
PATCH, 83, QUAD,, 118/ 119/ 167/ 166
PATCH, 84, QUAD,, 119/ 120/ 168/ 167
PATCH, 85, QUAD,, 121/ 122/ 170/ 169
PATCH, 86, QUAD,, 122/ 123/ 171/ 170
PATCH, 87, QUAD,, 123/ 124/ 172/ 171

```

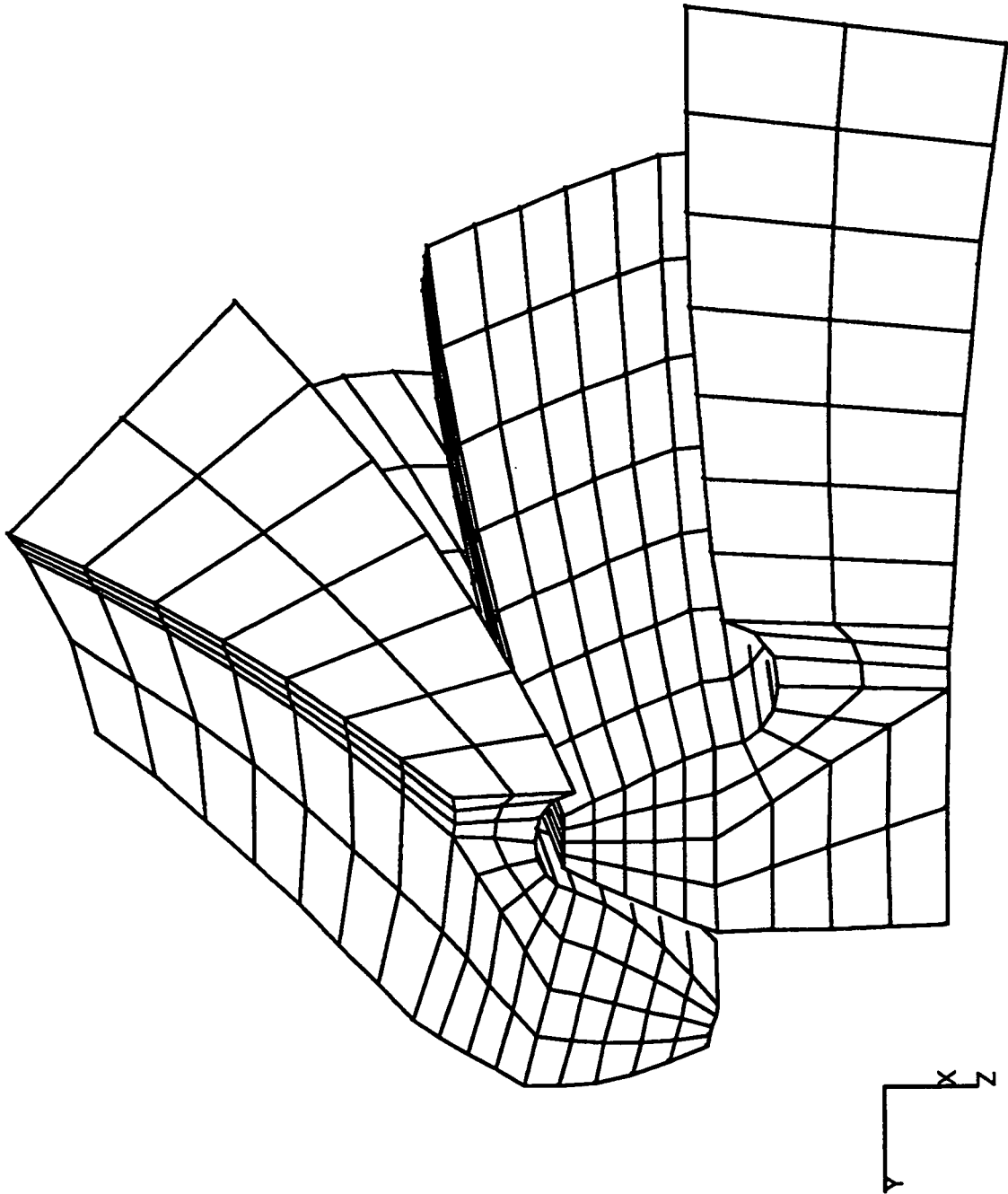
PATCH, 88, QUAD,, 124/ 125/ 173/ 172
 PATCH, 89, QUAD,, 125/ 126/ 174/ 173
 PATCH, 90, QUAD,, 127/ 128/ 176/ 175
 PATCH, 91, QUAD,, 128/ 129/ 177/ 176
 PATCH, 92, QUAD,, 129/ 130/ 178/ 177
 PATCH, 93, QUAD,, 130/ 131/ 179/ 178
 PATCH, 94, QUAD,, 131/ 132/ 180/ 179
 PATCH, 95, QUAD,, 133/ 134/ 182/ 181
 PATCH, 96, QUAD,, 134/ 135/ 183/ 182
 PATCH, 97, QUAD,, 135/ 136/ 184/ 183
 PATCH, 98, QUAD,, 136/ 137/ 185/ 184
 PATCH, 99, QUAD,, 137/ 138/ 186/ 185
 PATCH, 100, QUAD,, 139/ 140/ 188/ 187
 PATCH, 101, QUAD,, 140/ 141/ 189/ 188
 PATCH, 102, QUAD,, 141/ 142/ 190/ 189
 PATCH, 103, QUAD,, 142/ 143/ 191/ 190
 PATCH, 104, QUAD,, 143/ 144/ 192/ 191
 HPAT, 57,2P,, 65, 70
 HPAT, 58,2P,, 66, 71
 HPAT, 59,2P,, 67, 72
 HPAT, 60,2P,, 68, 73
 HPAT, 61,2P,, 69, 74
 HPAT, 62,2P,, 70, 75
 HPAT, 63,2P,, 71, 76
 HPAT, 64,2P,, 72, 77
 HPAT, 65,2P,, 73, 78
 HPAT, 66,2P,, 74, 79
 HPAT, 67,2P,, 75, 80
 HPAT, 68,2P,, 76, 81
 HPAT, 69,2P,, 77, 82
 HPAT, 70,2P,, 78, 83
 HPAT, 71,2P,, 79, 84
 HPAT, 72,2P,, 80, 85
 HPAT, 73,2P,, 81, 86
 HPAT, 74,2P,, 82, 87
 HPAT, 75,2P,, 83, 88
 HPAT, 76,2P,, 84, 89
 HPAT, 77,2P,, 85, 90
 HPAT, 78,2P,, 86, 91
 HPAT, 79,2P,, 87, 92
 HPAT, 80,2P,, 88, 93
 HPAT, 81,2P,, 89, 94
 HPAT, 82,2P,, 90, 95
 HPAT, 83,2P,, 91, 96
 HPAT, 84,2P,, 92, 97
 HPAT, 85,2P,, 93, 98
 HPAT, 86,2P,, 94, 99
 HPAT, 87,2P,, 95, 100
 HPAT, 88,2P,, 96, 101
 HPAT, 89,2P,, 97, 102
 HPAT, 90,2P,, 98, 103
 HPAT, 91,2P,, 99, 104
 GRID, 257,, -2.373271/ -0.090597/ 1.284378
 LINE, 153,, ,ARC,5(0)/1.0/ -5.8802 , 257
 GRID, 259,, -2.493672/ -0.177761/ 1.356060
 LINE, 154,, ,ARC,5(0)/1.0/ -5.9681 , 259
 GRID, 261,, -2.610745/ -0.273191/ 1.427743
 LINE, 155,, ,ARC,5(0)/1.0/ -6.0447 , 261
 GRID, 263,, -2.724029/ -0.377049/ 1.499426
 LINE, 156,, ,ARC,5(0)/1.0/ -6.1112 , 263
 GRID, 265,, -2.833021/ -0.489508/ 1.571109
 LINE, 157,, ,ARC,5(0)/1.0/ -6.1685 , 265
 GRID, 267,, -2.937172/ -0.610756/ 1.642791
 LINE, 158,, ,ARC,5(0)/1.0/ -6.2174 , 267
 GRID, 269,, -3.035876/ -0.740999/ 1.714474
 LINE, 159,, ,ARC,5(0)/1.0/ -6.2584 , 269

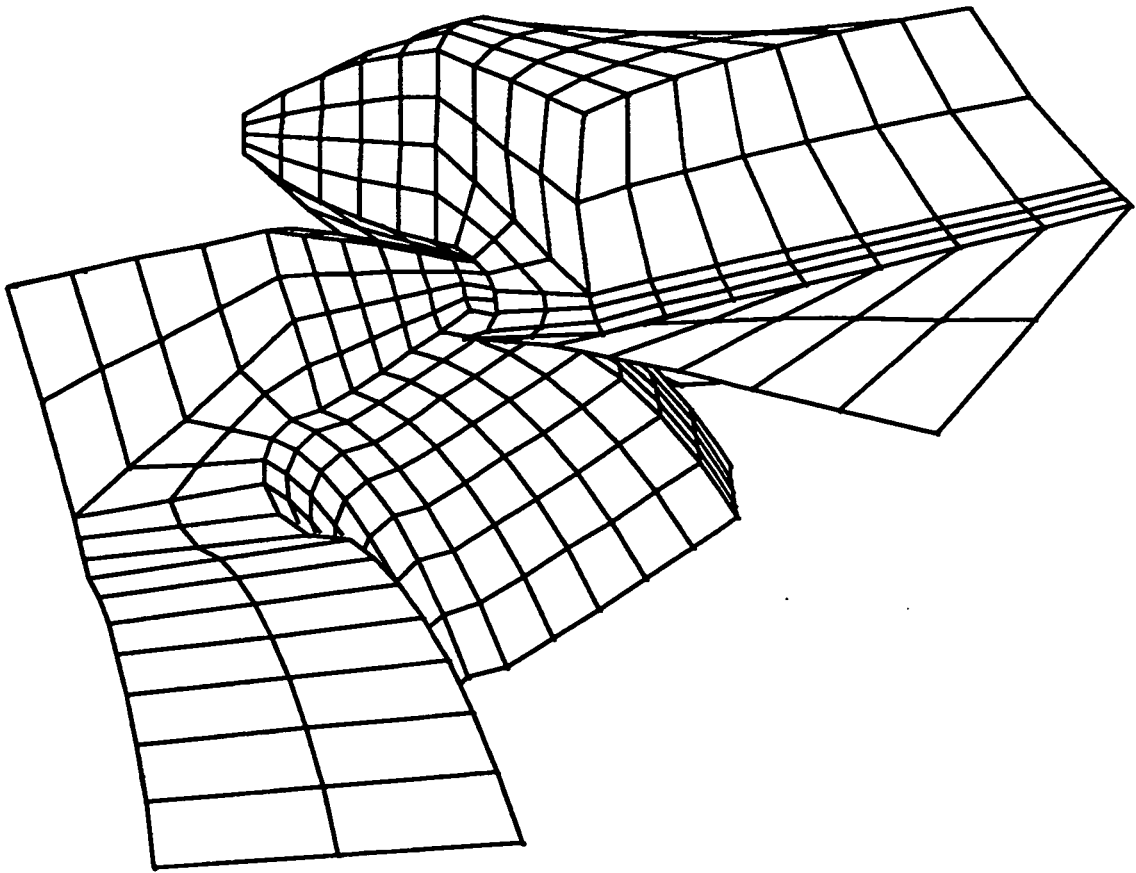
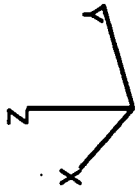
GRID, 271,, -3.128464/ -0.880463/ 1.786157
 LINE, 160 ,ARC,5(0)/1.0/ -6.2918 , 271
 LINE, 161,ARC,0/0/0/-2.4908/-0.1849/ 0.985636/-175.880, 97
 LINE, 177/ 178,BR,.5, 161
 LINE, 201 ,ARC,0/0/0/0/0/1/ 4.120, 257
 LINE, 218/ 219,BR,.5, 201
 LINE, 193,ST,, 249, 276
 LINE, 234,ST,, 274, 276
 LINE, 242,ST,, 145, 258
 LINE, 250,ST,, 273, 275
 LI, 258,MER,, 153/ 218
 LINE, 162,ARC,0/0/0/-2.6149/-0.2791/ 1.039882/-175.968, 103
 LINE, 179/ 180,BR,.5, 162
 LINE, 203 ,ARC,0/0/0/0/0/1/ 4.032, 259
 LINE, 220/ 221,BR,.5, 203
 LINE, 194,ST,, 250, 280
 LINE, 235,ST,, 278, 280
 LINE, 243,ST,, 151, 260
 LINE, 251,ST,, 277, 279
 LI, 259,MER,, 154/ 220
 LINE, 163,ARC,0/0/0/-2.7354/-0.3821/ 1.094129/-176.045, 109
 LINE, 181/ 182,BR,.5, 163
 LINE, 205 ,ARC,0/0/0/0/0/1/ 3.955, 261
 LINE, 222/ 223,BR,.5, 205
 LINE, 195,ST,, 251, 284
 LINE, 236,ST,, 282, 284
 LINE, 244,ST,, 157, 262
 LINE, 252,ST,, 281, 283
 LI, 260,MER,, 155/ 222
 LINE, 164,ARC,0/0/0/-2.8516/-0.4938/ 1.148375/-176.111, 115
 LINE, 183/ 184,BR,.5, 164
 LINE, 207 ,ARC,0/0/0/0/0/1/ 3.889, 263
 LINE, 224/ 225,BR,.5, 207
 LINE, 196,ST,, 252, 288
 LINE, 237,ST,, 286, 288
 LINE, 245,ST,, 163, 264
 LINE, 253,ST,, 285, 287
 LI, 261,MER,, 156/ 224
 LINE, 165,ARC,0/0/0/-2.9632/-0.6147/ 1.202622/-176.169, 121
 LINE, 185/ 186,BR,.5, 165
 LINE, 209 ,ARC,0/0/0/0/0/1/ 3.831, 265
 LINE, 226/ 227,BR,.5, 209
 LINE, 197,ST,, 253, 292
 LINE, 238,ST,, 290, 292
 LINE, 246,ST,, 169, 266
 LINE, 254,ST,, 289, 291
 LI, 262,MER,, 157/ 226
 LINE, 166,ARC,0/0/0/-3.0694/-0.7447/ 1.256868/-176.217, 127
 LINE, 187/ 188,BR,.5, 166
 LINE, 211 ,ARC,0/0/0/0/0/1/ 3.783, 267
 LINE, 228/ 229,BR,.5, 211
 LINE, 198,ST,, 254, 296
 LINE, 239,ST,, 294, 296
 LINE, 247,ST,, 175, 268
 LINE, 255,ST,, 293, 295
 LI, 263,MER,, 158/ 228
 LINE, 167,ARC,0/0/0/-3.1695/-0.8842/ 1.311115/-176.258, 133
 LINE, 189/ 190,BR,.5, 167
 LINE, 213 ,ARC,0/0/0/0/0/1/ 3.742, 269
 LINE, 230/ 231,BR,.5, 213
 LINE, 199,ST,, 255, 300
 LINE, 240,ST,, 298, 300
 LINE, 248,ST,, 181, 270
 LINE, 256,ST,, 297, 299
 LI, 264,MER,, 159/ 230
 LINE, 168,ARC,0/0/0/-3.2630/-1.0334/ 1.365361/-176.292, 139

LINE, 191/ 192,BR,.5, 168
 LINE, 215 ,ARC,0/0/0/0/0/1/ 3.708, 271
 LINE, 232/ 233,BR,.5, 215
 LINE, 200,ST,, 256, 304
 LINE, 241,ST,, 302, 304
 LINE, 249,ST,, 187, 272
 LINE, 257,ST,, 301, 303
 LI, 265,MER,, 160/ 232
 PA, 105,EDGE,, 242/ 138/ 193/ 258
 PA, 113,EDGE,, 193/ 137/ 177/ 234
 PA, 121,EDGE,, 234/ 178/ 250/ 219
 PA, 106,EDGE,, 243/ 140/ 194/ 259
 PA, 114,EDGE,, 194/ 139/ 179/ 235
 PA, 122,EDGE,, 235/ 180/ 251/ 221
 PA, 107,EDGE,, 244/ 142/ 195/ 260
 PA, 115,EDGE,, 195/ 141/ 181/ 236
 PA, 123,EDGE,, 236/ 182/ 252/ 223
 PA, 108,EDGE,, 245/ 144/ 196/ 261
 PA, 116,EDGE,, 196/ 143/ 183/ 237
 PA, 124,EDGE,, 237/ 184/ 253/ 225
 PA, 109,EDGE,, 246/ 146/ 197/ 262
 PA, 117,EDGE,, 197/ 145/ 185/ 238
 PA, 125,EDGE,, 238/ 186/ 254/ 227
 PA, 110,EDGE,, 247/ 148/ 198/ 263
 PA, 118,EDGE,, 198/ 147/ 187/ 239
 PA, 126,EDGE,, 239/ 188/ 255/ 229
 PA, 111,EDGE,, 248/ 150/ 199/ 264
 PA, 119,EDGE,, 199/ 149/ 189/ 240
 PA, 127,EDGE,, 240/ 190/ 256/ 231
 PA, 112,EDGE,, 249/ 152/ 200/ 265
 PA, 120,EDGE,, 200/ 151/ 191/ 241
 PA, 128,EDGE,, 241/ 192/ 257/ 233
 HPAT, 92 ,2P,, 105, 106
 HPAT, 99 ,2P,, 113, 114
 HPAT, 106 ,2P,, 121, 122
 HPAT, 93 ,2P,, 106, 107
 HPAT, 100 ,2P,, 114, 115
 HPAT, 107 ,2P,, 122, 123
 HPAT, 94 ,2P,, 107, 108
 HPAT, 101 ,2P,, 115, 116
 HPAT, 108 ,2P,, 123, 124
 HPAT, 95 ,2P,, 108, 109
 HPAT, 102 ,2P,, 116, 117
 HPAT, 109 ,2P,, 124, 125
 HPAT, 96 ,2P,, 109, 110
 HPAT, 103 ,2P,, 117, 118
 HPAT, 110 ,2P,, 125, 126
 HPAT, 97 ,2P,, 110, 111
 HPAT, 104 ,2P,, 118, 119
 HPAT, 111 ,2P,, 126, 127
 HPAT, 98 ,2P,, 111, 112
 HPAT, 105 ,2P,, 119, 120
 HPAT, 112 ,2P,, 127, 128
 SET,LINES,0
 NAME,GE 1
 SET,ACTIVE,NONE
 NAME,PI 1,PL
 MESH,H 1T 35,HEX,N,1/ 4/1/ 4/1
 MESH,H 36T 49,HEX,N, 2/ 4/ 2/ 4/1
 MESH,H 50T 56,HEX,N,3/ 2/3/ 2/1
 NAME,PIN
 SET,ACTIVE,NONE
 NAME,GE 1,PLOT
 MESH,H 57T 91,HEX,N,1/ 4/1/ 4/1
 MESH,H 92T 105,HEX,N, 4/ 2/ 4/ 2/1
 MESH,H 106T 112,HEX,N, 2/3/ 2/3/1

NAME, GEAR
GR, 1T#, DEL
NAME, PINION, RO, 4(0)/1/0/-90, PIN
NAME, PINION, PL

TYPICAL FE MESH





```

C                                     POINTS.F
C=====
C      POINTS.F GENERATES N BY M POINTS FOR THE PINION & GEAR SURFACES
C      POINTS.OUT => N BY M POINTS
C      (MAIN PROGRAM)
C
C      COMMON/CONST/PI,R,Q,MU,DEDEN,PSI,S,MCW,LM,EM,INC
C      DIMENSION XYZ(4),U(51),THETA(51),PHIC(51),D(3,3),F(3),Y(3)
C      DIMENSION RBAR(50,50),ZBAR(50,50),X1(50,50),X2(50,50),X3(50,50)
C      DOUBLE PRECISION MU,A1,B1,C1,D1,E1,AA,BB,CC,RV,MCW,Q,PSI,PI
C      DOUBLE PRECISION THETA,D,F,Y,GAMMA,DEDEN,R,S,TAU,EM,LM,PHIC
C      DOUBLE PRECISION XYZ,U,INC,ZBAR,RBAR,X1,X2,X3,LV,ADDAN,CL,RL,FW
C      INTEGER N1,N2,N3,M,UU,T,INT,BBB,CCC,SS
C
C      WRITE(*,(''PLEASE ENTER THE GRID PATTERN REQUIRED.'')
C      *''FOR EXAMPLE: FOR A 7X8 PATTERN, ENTER 7 AND RETURN''/
C      *''THEN ENTER 8 ''')')
C
C      READ(*,*)BBB
C      READ(*,*)CCC
C
C      PI      = 4.0 * ATAN(1.0)
C      INC     = 0.1
C      N1      = 11
C      N2      = 3
C      N3      = 4
C      DO 5 INT = 1,4
C
C      IF (INT .EQ. 1) THEN
C
C
C
C
C=====
C      DESCRIPTION OF INPUT DATA
C=====
C
C      1) RADIUS OF CUTTER, INCHES (R)
C      2) CRADLE ANGLE, DEGREES (Q)
C      3) BLADE ANGLE, DEGREES (PSI)
C      4) CRADLE TO CUTTER DISTANCE, INCHES (S)
C      5) RATIO OF ROLL (MCW)
C      6) MACHINE OFFSET, INCHES (EM)
C      7) VECTOR SUM, INCHES (LM)
C      8) DEDENDUM ANGLE, DEGREES (DEDEN)
C      9) PITCH ANGLE, DEGREES (MU)
C      10) ADDENDUM ANGLE, DEGREES (ADDAN)
C      11) CLEARANCE, INCHES (CL)
C      12) MEAN CONE DISTANCE, INCHES (RL)
C      13) FACE WIDTH, INCHES (FW)
C      14) INITIAL GUESS FOR SURFACE COORDINATE U ( U(1) )
C      15) INITIAL GUESS FOR SURFACE COORDINATE THETA ( THETA(1) )
C      16) INITIAL GUESS FOR ANGLE OF CRADLE, DEGREES ( PHIC(1) )
C=====
C      INSERT CONCAVE SIDE OF PINION DATA BELOW
C=====
C
C      R      = 2.96562137806
C      Q      = 63.9420304635 * PI/180.0
C      PSI     = 161.954330248 * PI/180.0
C      S      = 2.94780202969
C      MCW     = 0.30838512709

```

```

      EM      = 0.154575896
      LM      = 0.0384999977874
      DEDEN   = 1.56666666 * pi/180
      MU      = 18.4333333 * pi/180
      ADDAN   = 3.8833334 * pi/180
      CL      = 0.03
      RL      = 3.191
      FW      = 1.0
      U(1)    = 9.59703
      THETA(1) = 126.83544 * PI/180.0
      PHIC(1) = -0.85813 * PI/180.0
C
      ELSEIF (INT .EQ. 2) THEN
C=====
C      INSERT CONVEX SIDE OF PINION DATA BELOW
C=====
C
      R      = 3.071306157
      Q      = 53.9259945467 * PI/180.0
      PSI    = 24.337423854 * PI/180.0
      S      = 2.80104946
      MCW    = 0.3220428536
      EM      = -0.17426159493
      LM      = -0.0518138227
      DEDEN   = 1.56666666 * pi/180
      MU      = 18.4333333 * pi/180
      ADDAN   = 3.8833334 * pi/180
      CL      = 0.03
      RL      = 3.191
      FW      = 1.0
      U(1)    = 7.42534
      THETA(1) = 124.43689 * PI/180.0
      PHIC(1) = -11.38663 * PI/180.0
C
      ELSEIF (INT .EQ. 3) THEN
C=====
C      INSERT CONCAVE SIDE OF GEAR DATA BELOW
C=====
C
      R      = 3.0325
      Q      = 59.2342023 * PI/180.0
      PSI    = 158.0 * PI/180.0
      S      = 2.85995004691
      MCW    = 0.9508646
      EM      = 0.0
      LM      = 0.0
      DEDEN   = 3.8833333333 * pi/180
      MU      = 71.5666666 * pi/180
      ADDAN   = 1.5666666 * pi/180
      CL      = 0.0366
      RL      = 3.191
      FW      = 1.0
      U(1)    = 8.12602
      THETA(1) = 233.98994 * PI/180.0
      PHIC(1) = -0.35063 * PI/180.0
C=====
C
C
C
C
C
      ELSE
C
C=====
C      INSERT CONVEX SIDE OF GEAR DATA BELOW
C=====

```

```

C
      R      = 2.9675
      Q      = 59.2342023 * PI/180.0
      PSI    = 22.0 * PI/180.0
      S      = 2.85995004691
      MCW    = 0.9508646
      EM     = 0.0
      LM     = 0.0
      DEDEN  = 3.8833333333 * pi/180
      MU     = 71.5666666 * pi/180
      ADDAN  = 1.5666666 * pi/180
      CL     = 0.0366
      RL     = 3.191
      FW     = 1.0
      U(1)   = 7.89156
      THETA(1) = 234.95451 * PI/180.0
      PHIC(1) = -12.3384 * PI/180.0
ENDIF
C
OPEN(UNIT=900,FILE='POINTS.OUT',STATUS='UNKNOWN')
C
DO 10 UU = 1,BBB
DO 20 T = 1,CCC
C
CALL STEPZR(ZBAR,RBAR,UU,T,int,BBB,CCC,deden,mu,addan,cl,rl,fw)
C
SS = BBB - 1
DO 100 M = 1,SS
C
CALL DIFF(U,THETA,PHIC,M,D,N1,N2,UU,T,ZBAR,RBAR,INT)
C
IF ((INT .EQ. 1).OR.(INT .EQ. 2)) THEN
      TAU = (THETA(M)) - Q + (PHIC(M))
      GAMMA = MU - DEDEN
C
ELSEIF ((INT .EQ. 3).OR.(INT .EQ. 4)) THEN
      TAU = (THETA(M)) + Q - (PHIC(M))
      GAMMA = MU - DEDEN
ENDIF
C
      (THE FIRST EQUATION. (EQUATION OF MESHING FOR LEFT HAND PINION))
C
      A1 = ((U(M))-R*(COS(PSI)*COS(PSI)/SIN(PSI)))
      *COS(GAMMA)*SIN(TAU)
1
      B1 = S*(MCW-SIN(GAMMA))*COS(PSI)*SIN(THETA(M))
      C1 = S*COS(GAMMA)*SIN(PSI)*SIN(Q-(PHIC(M)))
      D1 = EM*(COS(GAMMA)*SIN(PSI)+SIN(GAMMA)*COS(PSI)*COS(TAU))
      E1 = LM*SIN(GAMMA)*COS(PSI)*SIN(TAU)
      IF ((INT .EQ. 1).OR.(INT .EQ. 2)) THEN
            LV = A1 + B1 - C1 + D1 - E1
            AA = LV
      ELSEIF ((INT .EQ. 3).OR.(INT .EQ. 4)) THEN
            RV = A1 + B1 + C1 - D1 - E1
            AA = RV
      ENDIF
C
      (THE SECOND EQUATION. ZW - Z = 0)
C
CALL TRANSF(U,THETA,PHIC,M,XYZ,N3,N1,INT)
C
      BB = XYZ(3) - ZBAR(UU,T)
C
      (THE THIRD EQUATION. R - SQRT( X*X + Y*Y ) = 0)
C
      CC = RBAR(UU,T) - SQRT(XYZ(1)*XYZ(1) + XYZ(2)*XYZ(2))

```

```

      F(1) = -AA
      F(2) = -BB
      F(3) = -CC
C
      CALL GAUSS(D,F,Y,N2)
C
      U(M+1) = U(M) + Y(1)
      THETA(M+1) = THETA(M) + Y(2)
      PHIC(M+1) = PHIC(M) + Y(3)
100  CONTINUE
C
      X1(UU,T) = XYZ(1)
      X2(UU,T) = XYZ(2)
      X3(UU,T) = XYZ(3)
C
      WRITE(900,*)X1(UU,T),X2(UU,T),X3(UU,T)
C
20  CONTINUE
10  CONTINUE
C
5  CONTINUE
   CLOSE(900,STATUS='KEEP')
C
   STOP
   END
C
   SUBROUTINE DIFF(X1,X2,X3,M,D,N1,N2,UU,T,ZBAR,RBAR,INT)
C
C   (THE VARIABLES X1,X2,X3; LOCAL TO THIS PROCEDURE; REPRESENT
C   U, THETA AND PHIC. )
C
   COMMON/CONST/PI,R,Q,MU,DEDEN,PSI,S,MCW,LM,EM,INC
   DIMENSION X1(N1),X2(N1),X3(N1),A(5,3),B(5,3),C(5,3),RVAL(5,3)
   DIMENSION XX1(51),XX2(51),XX3(51),D(N2,N2),XYZ(4),ZBAR(50,50)
   DIMENSION RBAR(50,50),LVAL(5,3)
   INTEGER I,J,L,UU,T
   DOUBLE PRECISION RVAL,A,B,C,K,H1,H2,H3,TAU,GAMMA,A1,B1,C1,D1
   DOUBLE PRECISION MU,DEDEN,PI,LM,MCW,X1,X2,X3,XX1,XX2,XX3,D
   DOUBLE PRECISION E1,INC,R,PSI,XYZ,EM,Q,S,ZBAR,RBAR,LVAL
C
C   (H1,H2,H3 ARE THE INCREMENTS ADDED TO THE)
C   (VAR X1,X2,X3 DURING THE NUMERICAL DIFF. )
C   (A1,B1,C1,D1,E1 INTERMEDIATE VALUES FOR EQU. OF MESHING)
C
   DO 201 I = 1,5
      L = I - 3
      K = L/2.0
C
C   (K IS THE MULTIPLIER ON THE INCREMENT "INC".)
C
      DO 205 J = 1,3
C
         IF (J .EQ. 1) THEN
            H1 = INC
            H2 = 0.
            H3 = 0.
         ELSE IF (J .EQ. 2) THEN
            H1 = 0.
            H2 = INC
            H3 = 0.
         ELSE
            H1 = 0.
            H2 = 0.
            H3 = INC
         ENDIF
C
      ENDIF

```



```

C      (* INSERT THE THREE EQUATIONS TO BE DIFFERENTIATED HERE *)
C      ( ADD K*H1, K*H2, K*H3 TO EACH VARIABLE X1,X2,X3 )
C
      IF ((INT .EQ. 1).OR.(INT .EQ. 2)) THEN
          TAU = (X2(M)+K*H2) - Q + (X3(M)+K*H3)
          GAMMA = MU - DEDEN
      ELSEIF ((INT .EQ. 3).OR.(INT .EQ. 4)) THEN
          TAU = (X2(M)+K*H2) + Q - (X3(M)+K*H3)
          GAMMA = MU - DEDEN
      ENDIF
C
C      (THE FIRST EQUATION. (EQUATION OF MESHING FOR LEFT HAND PINION))
C
      A1 = ((X1(M)+K*H1)-R*(COS(PSI)*COS(PSI)/SIN(PSI)))
      *COS(GAMMA)*SIN(TAU)
      B1 = S*(MCW-SIN(GAMMA))*COS(PSI)*SIN(X2(M)+K*H2)
      C1 = S*COS(GAMMA)*SIN(PSI)*SIN(Q-(X3(M)+K*H3))
      D1 = EM*(COS(GAMMA)*SIN(PSI) + SIN(GAMMA)*COS(PSI)*COS(TAU))
      E1 = LM*SIN(GAMMA)*COS(PSI)*SIN(TAU)
      IF ((INT .EQ. 1).OR.(INT .EQ. 2)) THEN
          LVAL(I,J) = A1 + B1 - C1 + D1 - E1
          A(I,J) = LVAL(I,J)
      ELSEIF ((INT .EQ. 3).OR.(INT .EQ. 4)) THEN
          RVAL(I,J) = A1 + B1 + C1 - D1 - E1
          A(I,J) = RVAL(I,J)
      ENDIF
C
C      (THE SECOND EQUATION. ZW - Z = 0)
C
      XX1(M) = X1(M) + K*H1
      XX2(M) = X2(M) + K*H2
      XX3(M) = X3(M) + K*H3
C
      CALL TRANSF(XX1, XX2, XX3,M,XYZ,N3,N1,INT)
C
      B(I,J) = XYZ(3) - ZBAR(UU,T)
C
C      (THE THIRD EQUATION. R - SQRT(X*X + Y*Y) = 0)
C
      C(I,J) = RBAR(UU,T) - SQRT(XYZ(1)*XYZ(1) + XYZ(2)*XYZ(2))
205      CONTINUE
C
201      CONTINUE
C
      DO 210 I = 1,3
          D(1,I) = -(A(5,I) - 8*A(4,I) - A(1,I) + 8*A(2,I))/(6*INC)
          D(2,I) = -(B(5,I) - 8*B(4,I) - B(1,I) + 8*B(2,I))/(6*INC)
          D(3,I) = -(C(5,I) - 8*C(4,I) - C(1,I) + 8*C(2,I))/(6*INC)
210      CONTINUE
C
      RETURN
      END
C
C
      SUBROUTINE TRANSF( X1,X2,X3,M,XYZ,N3,N1,INT)
C
      COMMON/CONST/PI,R,Q,MU,DEDEN,PSI,S,MCW,LM,EM,INC
      DIMENSION X1(N1),X2(N1),X3(N1),A(4),REST1(4,4)
      DIMENSION REST2(4,4),REST3(4,4),REST4(4,4),MSC(4,4),MMS(4,4)
      DIMENSION MPM(4,4),MAP(4,4),MWA(4,4),XYZ(N3)
      DOUBLE PRECISION INC,PI,MCW,Q,LM,MU,PSI,MSC,MMS,MPM,MAP,MWA
      DOUBLE PRECISION REST1,REST2,REST3,REST4,DEDEN,S,R,EM,PHIW
      DOUBLE PRECISION X1,X2,X3,A,XYZ
      INTEGER I,J,K
C
      DO 300 I = 1,4

```

```

C      DO 310 J = 1,4
          REST1(I,J)=0
          REST2(I,J)=0
          REST3(I,J)=0
          REST4(I,J)=0
          MSC(I,J)=0
          MMS(I,J)=0
          MPM(I,J)=0
          MAP(I,J)=0
          MWA(I,J)=0
310     CONTINUE
C
300     CONTINUE
C
          PHIW = X3(M)/MCW
C
C      ( THE COORDINATE TRANSFORMATIONS )
C
      IF ((INT .EQ. 1).OR.(INT .EQ. 2)) THEN
          MSC(1,1) = 1.0
          MSC(2,2) = COS(Q)
          MSC(2,3) = -SIN(Q)
          MSC(2,4) = -S*SIN(Q)
          MSC(3,2) = +SIN(Q)
          MSC(3,3) = COS(Q)
          MSC(3,4) = S*COS(Q)
          MSC(4,4) = 1.0
C
          MPM(1,1) = COS(DEDEN)
          MPM(1,3) = -SIN(DEDEN)
          MPM(1,4) = -LM*SIN(DEDEN)
          MPM(2,2) = 1.0
          MPM(2,4) = +EM
          MPM(3,1) = SIN(DEDEN)
          MPM(3,3) = COS(DEDEN)
          MPM(3,4) = LM*COS(DEDEN)
          MPM(4,4) = 1.0
C
          MMS(1,1) = 1.0
          MMS(2,2) = COS(X3(M))
          MMS(2,3) = +SIN(X3(M))
          MMS(3,2) = -SIN(X3(M))
          MMS(3,3) = COS(X3(M))
          MMS(4,4) = 1.0
C
          MAP(1,1) = COS(MU)
          MAP(1,3) = SIN(MU)
          MAP(2,2) = 1.0
          MAP(3,1) = -SIN(MU)
          MAP(3,3) = COS(MU)
          MAP(4,4) = 1.0
C
          MWA(1,1) = COS(PHIW)
          MWA(1,2) = +SIN(PHIW)
          MWA(2,1) = -SIN(PHIW)
          MWA(2,2) = COS(PHIW)
          MWA(3,3) = 1.0
          MWA(4,4) = 1.0
C
      ELSEIF ((INT .EQ. 3).OR.(INT .EQ. 4)) THEN
C
          MSC(1,1) = 1.0
          MSC(2,2) = COS(Q)
          MSC(2,3) = +SIN(Q)
          MSC(2,4) = +S*SIN(Q)

```

```

MSC(3,2) = -SIN(Q)
MSC(3,3) = COS(Q)
MSC(3,4) = S*COS(Q)
MSC(4,4) = 1.0
C
MPM(1,1) = COS(DEDEN)
MPM(1,3) = -SIN(DEDEN)
MPM(1,4) = -LM*SIN(DEDEN)
MPM(2,2) = 1.0
MPM(2,4) = -EM
MPM(3,1) = SIN(DEDEN)
MPM(3,3) = COS(DEDEN)
MPM(3,4) = LM*COS(DEDEN)
MPM(4,4) = 1.0
C
MMS(1,1) = 1.0
MMS(2,2) = COS(X3(M))
MMS(2,3) = -SIN(X3(M))
MMS(3,2) = +SIN(X3(M))
MMS(3,3) = COS(X3(M))
MMS(4,4) = 1.0
C
MAP(1,1) = COS(MU)
MAP(1,3) = SIN(MU)
MAP(2,2) = 1.0
MAP(3,1) = -SIN(MU)
MAP(3,3) = COS(MU)
MAP(4,4) = 1.0
C
MWA(1,1) = COS(PHIW)
MWA(1,2) = -SIN(PHIW)
MWA(2,1) = +SIN(PHIW)
MWA(2,2) = COS(PHIW)
MWA(3,3) = 1.0
MWA(4,4) = 1.0
C
ENDIF
C
C
C ( THE MATRIX MULTIPLICATIONS )
C
DO 320 I = 1,4
  DO 325 J = 1,4
    DO 330 K = 1,4
      REST1(I,J) = REST1(I,J) + MMS(I,K)*MSC(K,J)
    CONTINUE
  CONTINUE
CONTINUE
330
325
320
C
DO 335 I = 1,4
  DO 340 J = 1,4
    DO 345 K = 1,4
      REST2(I,J) = REST2(I,J) + MPM(I,K)*REST1(K,J)
    CONTINUE
  CONTINUE
CONTINUE
345
340
335
C
DO 350 I = 1,4
  DO 355 J = 1,4
    DO 360 K = 1,4
      REST3(I,J) = REST3(I,J) + MAP(I,K)*REST2(K,J)
    CONTINUE
  CONTINUE
CONTINUE
360
355
350
C
DO 365 I = 1,4
  DO 370 J = 1,4

```

```

DO 375 K = 1,4
  REST4(I,J) = REST4(I,J) + MWA(I,K)*REST3(K,J)
375  CONTINUE
370  CONTINUE
365  CONTINUE
C
DO 380 I = 1,4
  XYZ(I) = 0
380  CONTINUE
C
  A(1) = R*COS(PHI)/SIN(PHI)-X1(M)*COS(PHI)
  A(2) = X1(M)*SIN(PHI)*SIN(X2(M))
  A(3) = X1(M)*SIN(PHI)*COS(X2(M))
  A(4) = 1.0
C
DO 385 K = 1,4
  DO 390 I = 1,4
    XYZ(K) = XYZ(K) + REST4(K,I)*A(I)
390  CONTINUE
385  CONTINUE
C
RETURN
END
C
C
SUBROUTINE GAUSS(D,F,Y,N2)
C
  DIMENSION D(N2,N2),F(N2),Y(N2)
  DOUBLE PRECISION PIVOT,MULT,TOP,D,F,Y
  INTEGER I,J,K,N
C
  N = 3
C
DO 400 J = 1,N-1
  PIVOT = D(J,J)
C
DO 410 I = J+1,N
  MULT = D(I,J)/PIVOT
C
DO 420 K = J+1,N
  D(I,K) = D(I,K) - MULT * D(J,K)
  F(I) = F(I) - MULT * F(J)
420 CONTINUE
C
410 CONTINUE
C
  Y(N) = F(N)/D(N,N)
DO 430 I = N-1,1,-1
  TOP = F(I)
  DO 440 K = I+1,N
    TOP = TOP - D(I,K) * Y(K)
  Y(I) = TOP/D(I,I)
440 CONTINUE
C
430 CONTINUE
C
400 CONTINUE
C
RETURN
END
C
C
Subroutine stepzr(zbar,rbar,uu,t,int,bbb,ccc,deden,mu,addan
* ,cl,rl,fw)
C
  DIMENSION ZBAR(50,50),RBAR(50,50)

```

```

DOUBLE PRECISION ZPITCH,ZROOT1,ZM1,ZMX,ZINC1,ZM, RM, G, G9, Z, R
DOUBLE PRECISION ZBAR, RBAR, DEDEN, ADDAN, MU, CL, RL, FW
INTEGER DZ1, DR1, UU, T, BBB, CCC
PI      = 4.0*ATAN(1.0)

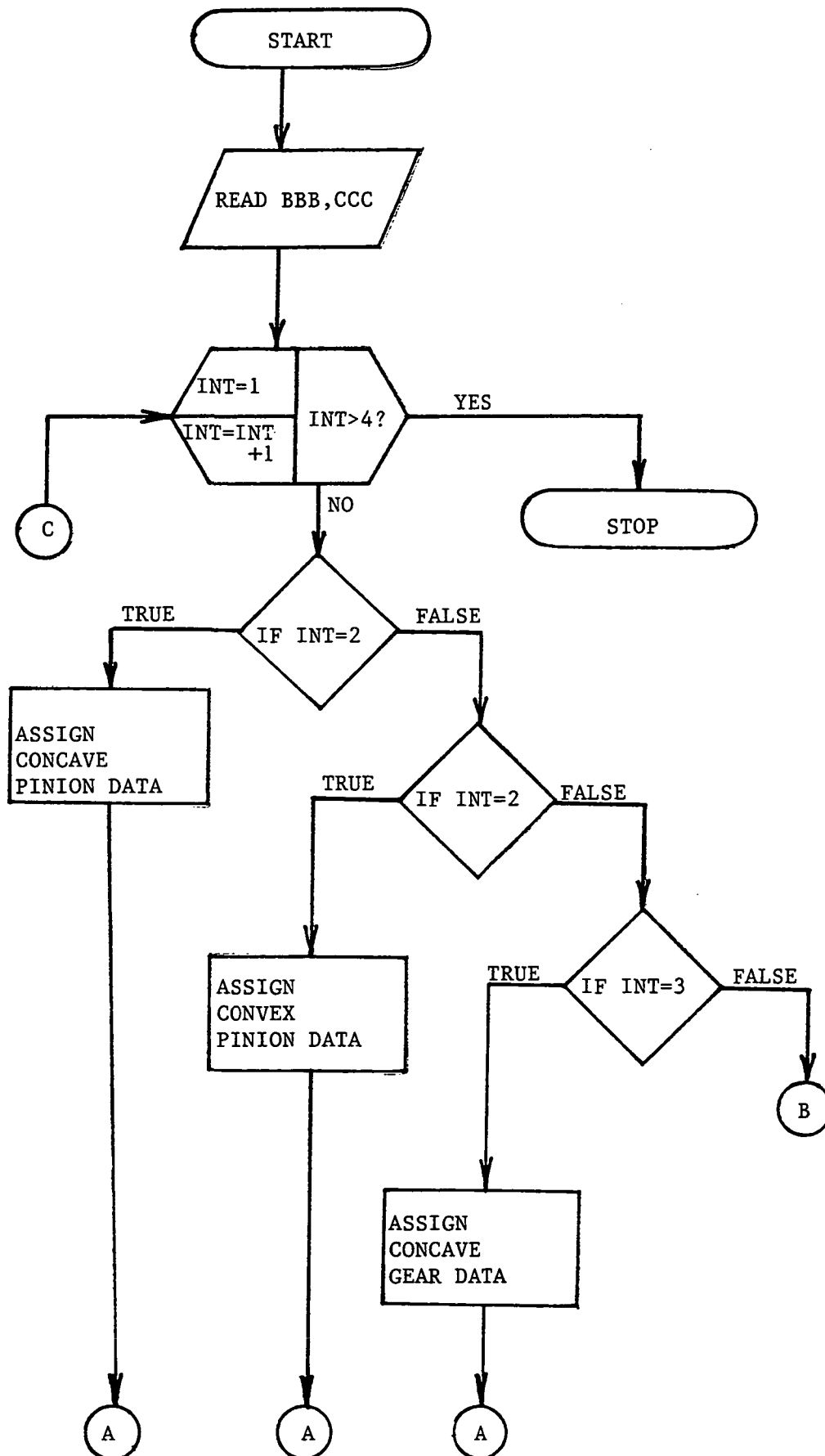
C
ZPITCH = RL - FW/2.0
ZROOT1 = ZPITCH * COS(DEDEN)
ZM1     = ZROOT1 * COS(MU - DEDEN)
ZMX     = (ZROOT1 + FW) * COS(MU - DEDEN)
ZINC1   = (ZMX - ZM1)/(BBB - 1)
Z       = 0.
R       = 0.

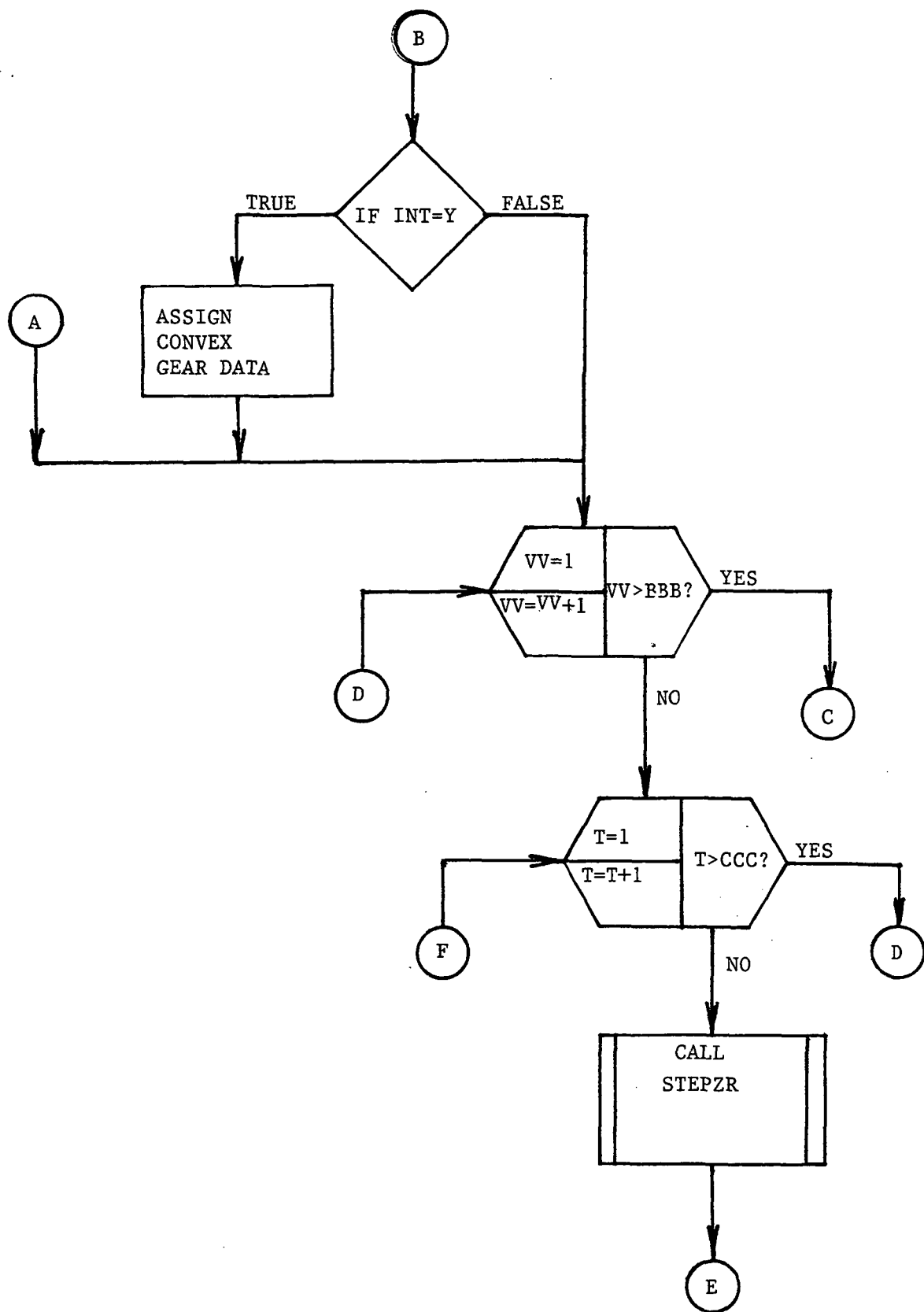
C
DZ1     = (UU - 1)
ZM      = ZM1 + DZ1*ZINC1 - CL * SIN(MU - DEDEN)
RM      = ZM * TAN(MU - DEDEN) + CL/COS(MU - DEDEN)
G       = ZM * TAN(ADDAN + DEDEN)/COS(MU - DEDEN) - CL
G9      = G/(CCC - 1)

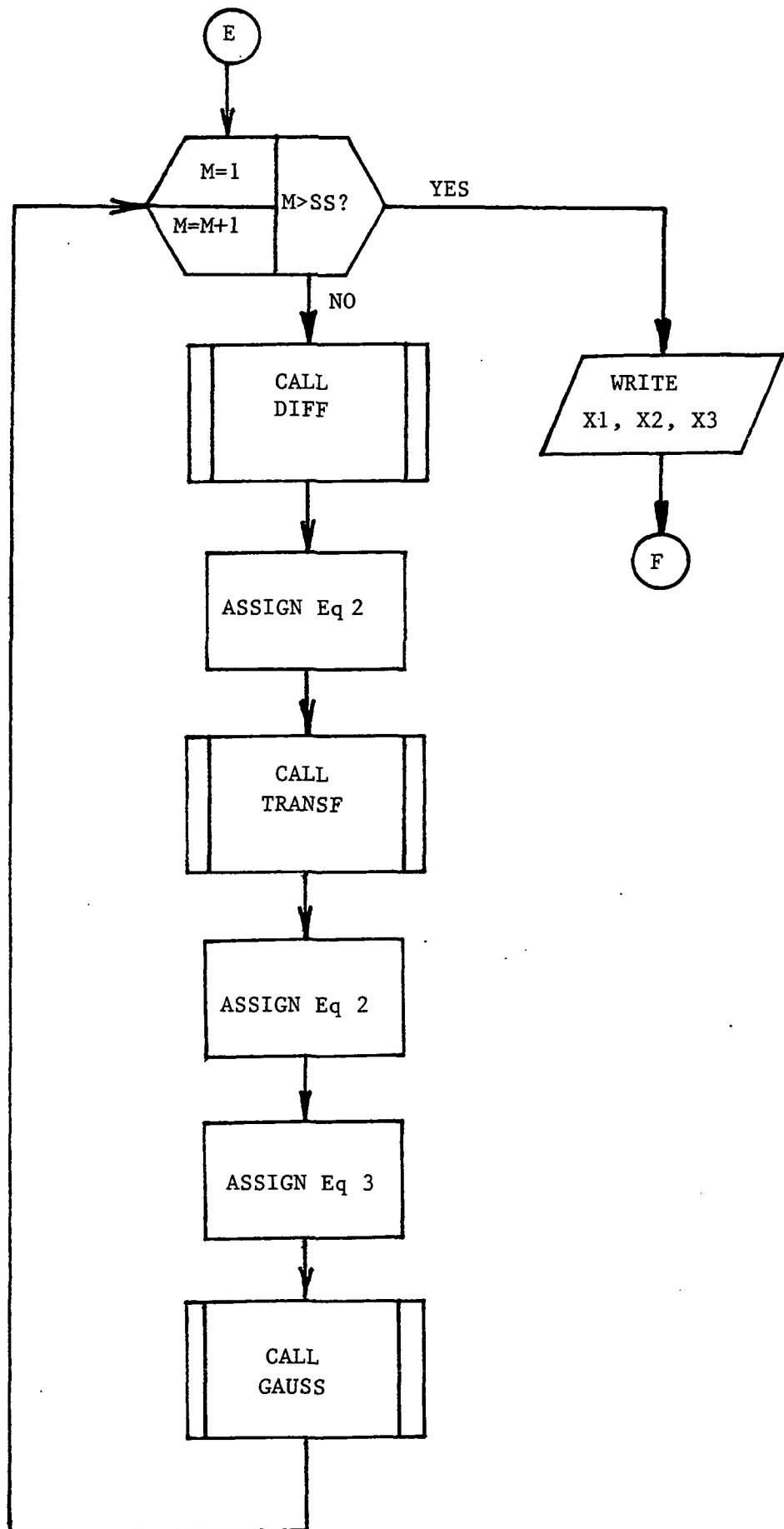
C
C
      dr1 = (T-1)
      Zbar(uu,t) = zm - dr1*g9*sin(mu-deden)
      rbar(uu,t) = rm + dr1*g9*cos(mu-deden)
RETURN
END

```

FLOWCHART: POINTS: F







FLOWCHART: POINTS.F (DISCUSSION)

There are 4 loops in the main program.

Loop 1: loops one through four to read data for the four surfaces.

Loop 2: loops one through BBB, where BBB is the number of points across the face of the tooth surface.

Loop 3: loops one through CCC, where CCC is the number of points along the length of the tooth height.

Loop 4: The final loop iterates to solve the three equations used to identify a point on the surface.

Subroutines:

1. STEPZR. This subroutine steps Z and R as the solution "marches" across the tooth face.
2. DIFF. This subroutine performs the numerical differentiation of the three equations (to form the Jacobian).
3. TRANSF. Subroutine that performs the matrix multiplication for the five coordinate transformations.
4. GAUSS. Uses gauss elimination to solve the Jacobian matrix.

```

C                                     PAT.F
C-----
C      THIS PROGRAM GIVES THE N * M GRID PATRAN INPUT FILE FOR      C
C      THE GENERATION OF SPIRAL BEVEL GEAR TOOTH SURFACE WITH FILLET  C
C-----C
C      READS POINTS.OUT AND GIVES T1.OUT
C      T1.OUT => INPUT FILE FOR PATRAN
C
C      (MAIN PROGRAM)
C
COMMON/UNITS/NF1,NF2
DIMENSION X1(45,45),X2(45,45),X3(45,45)
DIMENSION X1R(45,45),X2R(45,45),XX(8000),ZZ(8000),YY(8000)
DOUBLE PRECISION ri,cl,r1,r2,mu,deden,rogear
DOUBLE PRECISION X1,X2,X3,X1R,X2R,XX,YY,ZZ,rotcon,rotint
INTEGER UU,T,INT,NF1,NF2,NF3,JI,BB,CC
INTEGER NUMBER,FILL,NTPIN,NTGE

C      PI      = 4.0*ATAN(1.0)
C
NF1 = 900
NF2 = 1000
NF3 = 1001

C      OPEN(UNIT=NF1,FILE='t1.out',STATUS='UNKNOWN')
C      OPEN(UNIT=NF2,FILE='t2.out',STATUS='UNKNOWN')
C      OPEN(UNIT=NF3,FILE='POINTS.OUT',STATUS='OLD')

C      WRITE(*,('PLEASE ENTER THE REQUIRED GRID PATTERN.'/
C      *'FOR EXAMPLE : FOR A 8X7 PATTERN ENTER 8 AND THEN 7 >'))
C      READ(*,*)BB
C      READ(*,*)cc
C      write(*,*)'ENTER NUMBER OF ELEMENTS THROUGH THE THICKNESS'
C      READ(*,*) number
C      WRITE(*,*)'ENTER THE NUMBER OF ELEMENTS IN THE FILLET'
C      READ(*,*)FILL
C      DO 5 INT = 1,4
C      IF ((INT.EQ. 1).OR.(INT.EQ. 2)) THEN

C-----
C      DESCRIPTION OF INPUT DATA FOR PINION
C-----
C
C      1. DEDENDUM, DEGREES (DEDEN)
C      2. PITCH ANGLE, DEGREES (MU)
C      3. ROTATION OF CONVEX SURFACE TO
C      CREATE TOP LAND (ROTCON)
C      4. ROTATION OF PINION TO ELIMINATE
C      INTERFERENCE (ROTINT)
C      5. PINION ID, INCHES (RI)
C      6. CLEARANCE, INCHES (CL)
C      7. NUMBER OF PINION TEETH (NTPIN)
C-----
C
C-----
C      INPUT THE PINION DATA BELOW
C-----
C      DEDEN = 1.56666666 * PI/180.0
C      MU = 18.4333333 * PI/180.0
C      ROTCON = 2.275
C      ROTINT = -3.56
C      RI = 0.609375
C      CL = 0.03
C      NTPIN = 12
C-----

```

```

C
C
C
      ELSEIF ((INT .EQ. 3).OR.(INT .EQ. 4)) THEN
C
C
C-----
C      DESCRIPTION OF INPUT DATA FOR THE GEAR
C-----
C
C      1. DEDENDUM, DEGREES                      (DEDEN)
C      2. PITCH ANGEL, DEGREES                  (MU)
C      3. ROTATION OF CONVEX SURFACE TO
C          CREATE TOP LAND                      (ROTCON)
C      4. ROTATION OF GEAR TO PUT IN MESH        (ROGEAR)
C      5. CLEARANCE, INCHES                     (CL)
C      6. ID OF GEAR BASE                       (R1)
C      7. OD OF GEAR BASE                       (R2)
C      8. .NUMBER OF GEAR TEETH                 (NTGE)
C-----
C
C-----
C      INPUT THE GEAR DATA BELOW
C-----
C      DEDEN = 3.883333333 * PI/180.0
C      MU    = 71.56666666 * PI/180.0
C      ROTCON = -8.49
C      ROGEAR = 190.0
C      CL    = 0.0366
C      R1    = 2.375
C      R2    = 3.250
C      NTGE  = 36
C-----
C
C
C
C
C
C
C      ENDIF
C
C      IF (int.EQ.1) THEN
C          WRITE(NF1,*) 'SET,LABEL,OFF'
C          WRITE(NF1,*) 'VI'
C          WRITE(NF1,*) '1'
C          WRITE(NF1,*) '120,0,120'
C      ENDIF
C
C      JI = 1
C
C      DO 10 UU = 1,BB
C      DO 20 T  = 1,cc
C
C          READ(NF3,*)X1(UU,T),X2(UU,T),X3(UU,T)
C
C          IF ((INT .EQ. 2).OR.(INT .EQ. 4)) THEN
C              CALL ROTATE(X1(UU,T),X2(UU,T),X1R(UU,T),X2R(UU,T),INT,
C              * rotcon)
C          ENDIF
C
C          CALL ALLIGN(X1(UU,T),X2(UU,T),X1R(UU,T),X2R(UU,T),INT,
C          * rotint,rogear)
C
C          CALL GRID(UU,T,INT,X1,X2,X3,X1R,X2R,XX,YY,ZZ,bb,cc)
C
C          JI = JI + 1

```

```

C
20  CONTINUE
10  CONTINUE
5   CONTINUE
C
DO 6 int = 1,4
C
IF ((INT .EQ. 2).OR.(INT .EQ. 4)) THEN
CALL LINE(INT,bb,cc)
SS = INT
CALL PATCH(SS,bb,cc)
CALL HPAT(INT,bb,cc)
CALL FILLET(XX,YY,ZZ,INT,bb,cc,ri,cl,r1,r2,mu,deden,
* ntpin,ntge)
ENDIF
C
6   CONTINUE
C
CALL MODEL(bb,cc,number,fill)
CLOSE(NF3,STATUS='KEEP')
CLOSE(NF2,STATUS='KEEP')
CLOSE(NF1,STATUS='KEEP')
C
STOP
END
C
C
SUBROUTINE ROTATE(X1,X2,X1R,X2R,INT,rotcon)
C
COMMON/UNITS/NF1,NF2
DOUBLE PRECISION PI,Q,A,X1,X2,X1R,X2R,rotcon
DIMENSION A(2,2)
C
C ROTATION OF PINION AND GEAR CONVEX SIDES BY Q DEG. TO CREATE TOP LAND
C
PI = 4.0 * ATAN(1.0)
IF ((INT .EQ. 1).OR.(INT .EQ. 2)) THEN
Q = rotcon*PI/180.0
ELSEIF ((INT .EQ. 3).OR.(INT .EQ. 4)) THEN
Q = rotcon*PI/180.0
ENDIF
A(1,1) = COS(Q)
A(2,1) = -SIN(Q)
A(1,2) = SIN(Q)
A(2,2) = COS(Q)
C
X1R = X1*A(1,1)+X2*A(2,1)
X2R = X1*A(1,2)+X2*A(2,2)
C
RETURN
END
C
C
SUBROUTINE ALIGN(X1,X2,X1R,X2R,INT,rotint,rogear)
C
C TO ALIGN THE PINION ABOVE THE GEAR AND CALCULATE GAPS
C
COMMON/UNITS/NF1,NF2
DOUBLE PRECISION X1,X2,X1R,X2R,X11,X22,X11R,X22R
DOUBLE PRECISION Q,PI,X18,Y18,X18R,Y18R,rotint,rogear.
C
PI = 4.0 * ATAN(1.0)
C
C ROTATION OF THE PINION BY -3.56 DEG. ABOUT Z-AXIS
C
Q =rotint*PI/180.0

```

```

      IF (INT.EQ.1) THEN
        X11 = X1*COS(Q)-X2*SIN(Q)
        X22 = X1*SIN(Q)+X2*COS(Q)
        X1 = X11
        X2 = X22
      ELSEIF (INT.EQ.2) THEN
        X11R = X1R*COS(Q)-X2R*SIN(Q)
        X22R = X1R*SIN(Q)+X2R*COS(Q)
        X1R = X11R
        X2R = X22R
      ENDIF
C
Q = -30.0*PI/180.0
      IF (INT.EQ.1) THEN
        X30 = X1*COS(Q)-X2*SIN(Q)
        Y30 = X1*SIN(Q)+X2*COS(Q)
      ELSEIF (INT.EQ.2) THEN
        X30R = X1R*COS(Q)-X2R*SIN(Q)
        Y30R = X1R*SIN(Q)+X2R*COS(Q)
      ENDIF
C
C
C
      ROTATION OF THE GEAR BY 190 DEG. ABOUT Z-AXIS
C
Q = rogear*PI/180.0
      IF (INT.EQ.3) THEN
        X18 = X1*COS(Q)-X2*SIN(Q)
        Y18 = X1*SIN(Q)+X2*COS(Q)
        X1 = X18
        X2 = Y18
      ELSEIF (INT.EQ.4) THEN
        X18R = X1R*COS(Q)-X2R*SIN(Q)
        Y18R = X1R*SIN(Q)+X2R*COS(Q)
        X1R = X18R
        X2R = Y18R
      ENDIF
C
C
      RETURN
      END
C
C
      SUBROUTINE GRID(UU,T,INT,X1,X2,X3,X1R,X2R,XX,YY,ZZ,BB,cc)
C
      COMMON/UNITS/NF1,NF2
      INTEGER NN,UU,T,BB,cc
      DOUBLE PRECISION X1(45,45),X2(45,45),X3(45,45)
      DOUBLE PRECISION X1R(45,45),X2R(45,45)
      DOUBLE PRECISION XX(8000),YY(8000),ZZ(8000)
      IF (INT.EQ. 1) THEN
        NN = (UU - 1) * cc + T
      ELSEIF (INT.EQ. 2) THEN
        NN = (UU - 1) * cc + T + (BB*cc)
      ELSEIF (INT.EQ. 3) THEN
        NN = (UU - 1) * cc + T + 2*(BB*cc)
      ELSEIF (INT.EQ. 4) THEN
        NN = (UU - 1) * cc + T + 3*(BB*cc)
      ENDIF
C
      IF ((INT.EQ. 1).OR.(INT.EQ. 3)) THEN
        XX(NN) = X1(UU,T)
        YY(NN) = X2(UU,T)
        ZZ(NN) = X3(UU,T)
      ELSEIF ((INT.EQ. 2).OR.(INT.EQ. 4)) THEN
        XX(NN) = X1R(UU,T)
        YY(NN) = X2R(UU,T)
        ZZ(NN) = X3(UU,T)

```



```

      j = k + (cc-1)
      WRITE(nf1,810)'HPAT',',',',K',',',',2P',',',',K',',',J
      ELSEIF (INT.EQ. 4) THEN
        K = I + (BB-1)*(cc-1) + 3*(bb-1)
        L = (cc-1)*bb + i + 3*bb
        J = L + (cc-1)
      WRITE(NF1,810)'HPAT',',',',K',',',',2P',',',',L',',',J
      ENDIF
810  FORMAT(A4,A1,I4,A1,A2,A2,I4,A1,I4)
800  CONTINUE
C
      RETURN
      END
C
C
C
C
      SUBROUTINE FILLET(XX,YY,ZZ,INT,bb,cc,ri,cl,r1,r2,mu,deden,
* ntpin,ntge)
C
C      FINDING INNER GEAR BLANK RADIUS GRIDS & ARC LOCATIONS
C
      COMMON/UNITS/NF1,NF2
      INTEGER I,J,K,II,JJ,KK,AR,HP,LI,GR,LS1,LF,PS,PF,PAT
      INTEGER PA,G,NN,HPA,IP,bb,cc,SS
      INTEGER PA1,PA2,PA3,PA4
      INTEGER pa5,pa6,pa7,pa8,pa9,pa10,pa11,pa12
      INTEGER hh1,hh2,hh3,hp1,hp2,hp3,hp4,hp5,hp6,ggb1,ggb2,pppa
      DOUBLE PRECISION PI,RI,MM(100),XX(8000),YY(8000),ZZ(8000)
      DOUBLE PRECISION DELA,DELR,RBAR,R1,R2,ANG,MU,DEDEN,ETA,ROT
      DOUBLE PRECISION PP(100),DELTA(100),X(8000),Y(8000),Z(8000)
      DOUBLE PRECISION XR,YR,ZR,XRHO,YRHO,VEC,ROTAT,cl
      DOUBLE PRECISION RX(100),RY(100),RZ(100)
      INTEGER Li1,Li2,Li3,Li4,Li5,Li6,Li7,Li8,Li9
      INTEGER Li10,Li11,Li12,Li13,Li14,Li15,Li16,Li17,Li18,Li19
      INTEGER W1,w2,w3,w4,w5,w6,w7,w8,w9,w10,w11,w12,w13,w14
      INTEGER w15,w16,w17,w18,w19
      INTEGER ntp,ntpin,ntge
C
      LL = 4*(BB*cc)
      DO 125 NN = 1,LL
        X(NN) = XX(NN)
        Y(NN) = YY(NN)
        Z(NN) = ZZ(NN)
125  CONTINUE
C
      Do 130 nn = LL +bb, 4*bb*cc +bb
        x(nn-bb) = xx(nn)
        Y(nn-bb) = yy(nn)
        z(nn) = zz(nn)
C130 CONTINUE
C      FOR INSIDE RADIUS COORDINATES UNDER THE GEAR TOOTH
C
        PI = 3.141592654
        IF(INT.EQ.2)THEN
          GR = LL
          PI = 3.141592654
        ENDIF
C
        IF(INT.EQ.4) THEN
          GR = LL + 6*BB
          PI = 3.141592654
        ENDIF
C
      DO 155 I = 1,BB
        IF(INT.EQ.2)THEN

```

```

JJ = (I-1)*cc + 1
KK = (I-1)*cc + BB*cc + 1
J = I + BB
IF (ABS(Y(JJ)).LE.1.0E-5)GOTO 141
MM(I) = ATAN(Y(JJ)/X(JJ))
IF (X(JJ).LT.0.0.AND.Y(JJ).LT.0.0)MM(I) = MM(I) + PI
IF (X(JJ).LT.0.0.AND.Y(JJ).GT.0.0)MM(I) = MM(I) + PI
GOTO 142
141 CONTINUE
MM(I) = 0.0
IF (Z(JJ).LT.0.0)MM(I) = PI
142 CONTINUE
IF (ABS(Y(KK)).LT.1.E-5)GOTO 143
PP(J) = ATAN(Y(KK)/X(KK))
IF (X(KK).LT.0.0.AND.Y(KK).LT.0.0)PP(J) = PP(J) + PI
IF (X(KK).LT.0.0.AND.Y(KK).GT.0.0)PP(J) = PP(J) + PI
GOTO 140
143 CONTINUE
PP(J) = 0.0
IF (X(KK).LT.0.0)PP(J) = PI
140 GOTO 155
C
ELSEIF(INT.EQ.4)THEN
JJ = (I-1)*cc + 2*(BB*cc)+1
KK = (I-1)*cc + 3*(BB*cc)+1
J = I + 2*(BB*cc) + BB
IF (ABS(Y(JJ)).LE.1.0E-5)GOTO 151
MM(I) = ATAN(Y(JJ)/X(JJ))
IF (X(JJ).LT.0.0.AND.Y(JJ).LT.0.0)MM(I) = MM(I) + PI
IF (X(JJ).LT.0.0.AND.Y(JJ).GT.0.0)MM(I) = MM(I) + PI
GOTO 152
151 CONTINUE
MM(I) = 0.0
IF (X(JJ).LT.0.0)MM(I) = PI
152 CONTINUE
IF (ABS(Y(KK)).LT.1.E-5)GOTO 153
PP(J) = ATAN(Y(KK)/X(KK))
IF (X(KK).LT.0.0.AND.Y(KK).LT.0.0)PP(J) = PP(J) + PI
IF (X(KK).LT.0.0.AND.Y(KK).GT.0.0)PP(J) = PP(J) + PI
GOTO 150
153 CONTINUE
PP(J) = 0.0
IF (X(KK).LT.0.0)PP(J) = PI
150 GOTO 155
ENDIF
155 CONTINUE
C
C
C FOR INNER GEAR BLANK RADIUS GRIDS & ARC LOCATIONS
IF(INT.EQ.4)THEN
    DELR = (R2-R1)/(BB-1)
    RBAR = R1
ENDIF
C
DO 910 I = 1, BB
    J = I + BB
    G = GR + 1 + (I-1)*2
C
IF(INT.EQ.2)THEN
    JJ = (I-1)*cc + 1
    K = I + 2*BB
    XR = RI*COS(MM(I))
    YR = RI*SIN(MM(I))
    ZR = Z(JJ)
    DELTA(I) = ((PP(J)-MM(I))*180./PI)
    WRITE(nf1,915)'GRID','G+bb',',',',',XR,'/',YR,'/',ZR

```



```

911      WRITE(nf1,911)'LINE','k+bb','ARC,5(0)/1/',delta(i),',',',g+bb
        FORMAT(a5,i3,a12,f10.5,a1,i4)

```

C

```

        ELSEIF(INT.EQ.4)THEN
          JJ = (I-1)*cc + 2*(BB*cc)+1
          J  = I + 2*(BB*cc)+BB
          K  = I + (cc-1)*BB
          RBAR = R1 + (I-1)*DELR
          RX(I) = RBAR*COS(MM(I))
          RY(I) = RBAR*SIN(MM(I))
          RICC = SQRT(X(JJ)*X(JJ)+Y(JJ)*Y(JJ))
          RZ(I) = Z(JJ) + (RICC-RBAR)/TAN(PI/2.-(MU-DEDEN))
          DELTA(I) = (PP(J)-MM(I))*180./PI
          WRITE(nf1,915)'GRID','G+2*bb','',',',RX(i),',',',Ry(i),',',',Rz(i)
        WRITE(nf1,920)'LINE','19*bb+i','ARC,5(0)/1.0/',delta(i),',',',g+2*bb
        ENDIF
915      FORMAT(A5,I4,A2,F10.6,A1,F10.6,A1,F10.6)
920      FORMAT(A5,I4,A20,F10.4,A2,I4)
910      CONTINUE
925      CONTINUE

```

C

C

C

TO MAKE HYPAT FROM GEAR BLANK INSIDE RADIUS TO TOOTH BOTTOM

```

        IF(INT.EQ.2)THEN
          GR = 4*BB*cc
          PA = 2*BB*cc - BB
          LI = 3*BB
          HP = 2*(cc-1)*(bb-1) + (BB-1)
          ntp = ntpin
        ELSEIF(INT.EQ.4)THEN
          GR = 4*BB*cc + 6*BB
          PA = 2*BB*cc + BB
          LI = BB*cc
          HP = 2*(cc-1)*(bb-1) + 3*(BB-1)
          ntp = ntge
        ENDIF
        NT = FLOAT(NTP)

```

C

C

```

        DO 930 I = 1,BB
          LI = LI + i
        IF(INT.EQ.2)THEN
          Li1 = 4*bb + 2*i
          Li2 = 4*bb*cc + bb + (2*i-1)
          Li3 = 10*bb+(2*i-1)
          Li4 = 10*bb+2*i
          Li5 = Li1
          Li6 = 12*bb+i
          Li7 = 4*bb*cc + 3*bb +(4*i-2)
          Li8 = 4*bb*cc +3*bb +4*i
          Li9 = 13*bb+i
          Li10 = bb*cc+cc*i-(cc-1)
          Li11 = 4*bb*cc+bb+(2*i)
          Li12 = 14*bb+i
          Li13 = 4*bb*cc +3*bb +(4*i-3)
          Li14 = 4*bb*cc +3*bb +(4*i-1)
          Li15 = 15*bb+i
          Li16 = 3*bb+i
          Li17 = 10*bb+(2*i-1)
          II = (I-1)*cc + 1
          DELA = ABS(DELTA(I)*PI/180.)
          ROT = (2.* PI / NT - DELA)/2.
          VEC = SQRT(X(II)*X(II)+Y(II)*Y(II))
          ETA = ACOS(1.-(CL/VEC)**2.)
          XRHO = VEC*COS(MM(I)-ROT)

```

```

      YRHO = VEC*SIN(MM(I)-ROT)
      ANG = ((PI-2.*ROT)*180.)/ PI
      W4 = 8*bb + i
      W5 = 4*bb*cc + i
      W6 = 4*bb*cc + 3*bb + 4*i
      WRITE(nf1,929)'LINE','4*bb+(2*i-1)',',ARC','xrho','/',',yrho','/0/',
*      xrho','/',',yrho','/1.0/',',ang','/',',ii
      WRITE(nf1,933)'LINE','6*bb+(2*i-1)',',/',',6*bb+2*i',',BR,.5',',
*      4*bb+(2*i-1)

933  FORMAT (a5,i4,a1,i4,a7,i4)

929  FORMAT(a5,i4,a5,f8.5,a1,f8.5,a3,f8.5,a1,f8.5,a5,f11.5,a1,i4)
934  FORMAT(a5,i4,a3,a2,i4,a1,i4)
      ELSE
          Li1 = 25*bb+(2*i-1)
          Li2 = 4*cc*bb + 8*bb + (2*i - 1)
          Li3 = 27*bb + 2*i
          Li4 = 27*bb + 2*i + 1
          Li5 = 25*bb+(2*i-1)
          Li6 = 29*bb + 1 + i
          Li7 = 4*bb*cc + 10*bb + (4*i -2)
          Li8 = 4*bb*cc +10*bb + 4*i
          Li9 = 30*bb + 1 + i
          Li10 = 3*cc*bb + (cc*i - cc+1)
          Li11 = 4*bb*cc + 8*bb + 2*i
          Li12 = 31*bb + 1 + i
          Li13 = 4*bb*cc + 10*bb + (4*i - 3)
          Li14 = 4*bb*cc + 10*bb + (4*i - 1)
          Li15 = 32*bb + 1 + i
          Li16 = 19*bb + i
          Li17 = 27*bb + 2*i
          II = (I-1)*cc + 2*(BB*cc)+1
          DELA = ABS(DELTA(I)*PI/180.)
          ROT = (2.* PI / NT - DELA)/2.
          VEC = SQRT(X(II)*X(II)+Y(II)*Y(II))
          XRHO = VEC*COS(MM(I)+ROT)
          YRHO = VEC*SIN(MM(I)+ROT)
          ANG = -((PI-2.*ROT)*180.)/ PI
          WRITE(NF1,931)'LINE','20*bb+i',',ARC','','0/0/0/','XRHO','/',
*          YRHO','/',',Z(II)',',/',',ANG','/',',II
          W1 = 22*bb + (2*i-1)
          W2 = W1 +1
          W3 = 20*bb+i
          W4 = 24*bb + i
          W5 = 4*bb*cc + 7*bb + i
          W6 = 4*bb*cc + 10*bb + 4*i
          WRITE(nf1,933)'LINE','w1','/',',w2',',BR,.5',',w3
931  FORMAT(A5,I4,A5,A6,F7.4,A1,F7.4,A1,F10.6,A1,F8.3,A1,I4)
      ENDIF
      IF(INT.EQ.2)ROTAT = -(2 * ROT * 180./PI)
      IF(INT.EQ.4)ROTAT = (2 * ROT * 180./PI)
      IF(I.EQ.1)GR = GR + 1
      IF(I.GT.1)GR = GR + 2
      Write(nf1,932)'LINE','LI1, ',',ARC,0/0/0/0/0/1/',',ROTAT','/',',LI2
      write(nf1,936)'LINE','LI3, ',',',',',LI4, ',',BR,.5',',LI5
      write(nf1,934)'LINE','w4',',ST',',',',w5',',',w6
      write(nf1,937)'LINE','LI6',',ST',',',',LI7',',',LI8
      write(nf1,937)'LINE','LI9',',ST',',',',LI10',',',LI11
      write(nf1,937)'LINE','LI12',',ST',',',',LI13',',',LI14
      write(nf1,938)'LI','LI15',',MER,,',LI16,'/',',LI17
938  format(a3,i4,a6,i4,a1,i4)
937  format(a5,i4,a3,a2,i4,a1,i4)
936  format(a5,i4,a1,i4,a7,i4)
932  FORMAT(A5,I4,A18,F8.3,A1,I4)
930  CONTINUE

```

C
C
C
C

CONNECT LINES ON TOP OF FILLET/ROOT RADIUS & GEAR BLANK INSIDE RADIUS

```
DO 940 I = 1,bb
  IF(INT.EQ.2) then
    pppa = bb*cc-bb
    pa1 = bb+2*i
    pa2 = 13*bb+i
    pa3 = 15*bb+i
    pa4 = 8*bb+i
    pa5 = bb+(2*i-1)
    pa6 = 8*bb+i
    pa7 = 12*bb+i
    pa8 = 6*bb+(2*i-1)
    pa9 = 10*bb+(2*i)
    pa10 = 14*bb+i
    pa11 = 6*bb+2*i
    pa12 = 12*bb+i
  elseif(int.eq.4)then
    Pppa = 2*bb*(cc-1) + 3*bb
    pa1 = 30*bb + 1 + i
    pa2 = 17*bb + 2*i
    pa3 = 24*bb + i
    pa4 = 32*bb + 1 + i
    pa5 = pa3
    pa6 = pa2 - 1
    pa7 = 22*bb + 2*i -1
    pa8 = 29*bb + 1 + i
    pa9 = pa8
    pa10 = pa7 + 1
    pa11 = 31*bb + i + 1
    pa12 = 27*bb + 2*i + 1
  endif
  write(nf1,941)'PA,',1*PPPA+i,',EDGE,,,pa1,/',pa2,/',pa3,/',pa4
  write(nf1,941)'PA,',1*PPPA+bb+i,',EDGE,,,pa5,/',pa6,/',pa7,/',pa8
  write(nf1,941)'PA,',1*pppa+2*bb+i,',EDGE,,,pa9,/',pa10,/',pa11,
  *,',pa12
941  format(a3,i4,a7,i4,a1,i4,a1,i4,a1,i4)
940  CONTINUE
```

C
C
C

CONNECT PATCHES IN BETWEEN TEETH TO MAKE HYPERPATCHES

```
do 945 i = 1,(bb-1)
  If (int.eq.2) then
    hp1 = bb*(cc-1) + i
    hp2 = hp1 + 1
    hp3 = hp1 + bb
    hp4 = hp3 + 1
    hp5 = hp3 + bb
    hp6 = hp5 + 1
    hh1 = (bb-1)*(cc-1)+i
    hh2 = hh1 + (bb-1)
    hh3 = hh2 + (bb-1)
  ELSEIF (INT .EQ. 4) THEN
    hp1 = 2*bb*(cc-1) + 3*bb + i
    hp2 = hp1 + 1
    hp3 = hp1 + bb
    hp4 = hp3 + 1
    hp5 = hp3 + bb
    hp6 = hp5 + 1
    hh1 = 2*(bb-1)*(cc-1) + 3*(bb-1) + i
    hh2 = hh1 + bb-1
    hh3 = hh2 + bb-1
  ENDIF
  write(nf1,913)'HPAT,',hh1,',2P,,,hp1,',',hp2
```

```

        write(nf1,913)'HPAT','hh2','2P','','hp3','','hp4
        write(nf1,913)'HPAT','hh3','2P','','hp5','','hp6
913  format(a5,i4,a6,i4,a1,i4)
945  CONTINUE
    IF(INT.EQ.2)GO TO 980
C
980  CONTINUE
    IF (INT.EQ.2) THEN
        WRITE(NF1,*)'SET,LINES,0'
        WRITE(NF1,*)'NAME,PI 1'
        WRITE(NF1,*)'SET,ACTIVE,NONE'
    ELSEIF(INT.EQ.4) THEN
        WRITE(NF1,*)'SET,LINES,0'
        WRITE(NF1,*)'NAME,GE 1'
        write(nf1,*)'SET,ACTIVE,NONE'
    ENDIF
C
    RETURN
    END
C
C
C
    SUBROUTINE MODEL(BB,cc,number,fill)
C
    COMMON/UNITS/NF1,NF2
    INTEGER I,J,K,L,numb
    INTEGER I1,I2,J1,J2,K1,K2,L1,L2,bb,cc
C
        WRITE(NF1,*)'NAME,GE 1,PLOT'
C    to generate the whole gear use this do loop
C    DO 901 I = 1,35
C        L = I + 1
C        WRITE(NF1,905)'NAME','','GE',L','','','RO','','','5(0)/1/10','','GE',I
C 905  FORMAT(A6,A2,I2,A1,A2,A1,A10,A2,I2)
C 901  CONTINUE
C        WRITE(NF1,*)'NAME,GEAR'
C        write(nf1,*)'NAME,PI 1,PL'
C        WRITE(NF1,*)'PA,1T#,DEL'
C
C        I1 = 1
C        I2 = (BB-1)*(cc-1)
C        j1 = i2 + 1
C        j2 = i2 + 2*(bb-1)
C        numb = number/2
C
        write(nf1,917)'MESH,H',i1,'T',i2,'HEX,N,1/',number
        *,'/1/',number,'/1'
        write(nf1,918)'MESH,H',j1,'T',j2,'HEX,N',numb,'/',
        * fill,'/',numb,'/',fill,'/1'
        write(nf1,919)'MESH,H',j2+1,'T',j2+bb-1,'HEX,N','','3',
        * '/',numb,'/3/',numb,'/1'
C 919  format(a6,i4,a1,i4,a7,a1,a1,i4,a3,i4,a2)
C 917  format(a6,i4,a1,i4,a9,i4,a3,i4,a2)
C 918  format(a6,i4,a1,i4,a7,i4,a1,i4,a1,i4,a2)
        write(nf1,*)'NAME,PIN'
        WRITE(NF1,*)'SET,ACTIVE,NONE'
        WRITE(NF1,*)'NAME,GE 1,PLOT'
C
C        K1 = (bb-1)*(cc-1) + 3*(bb-1) + 1
C        K2 = K1 + (bb-1) *(cc-1) - 1
C        JJ1 = K2 + 1
C        jj2 = k2 + 2*(bb-1)
C        numb = number/2
C
C        write(nf1,917)'MESH,H',K1,'T',K2,'HEX,N,1/',number
        *,'/1/',number,'/1'

```

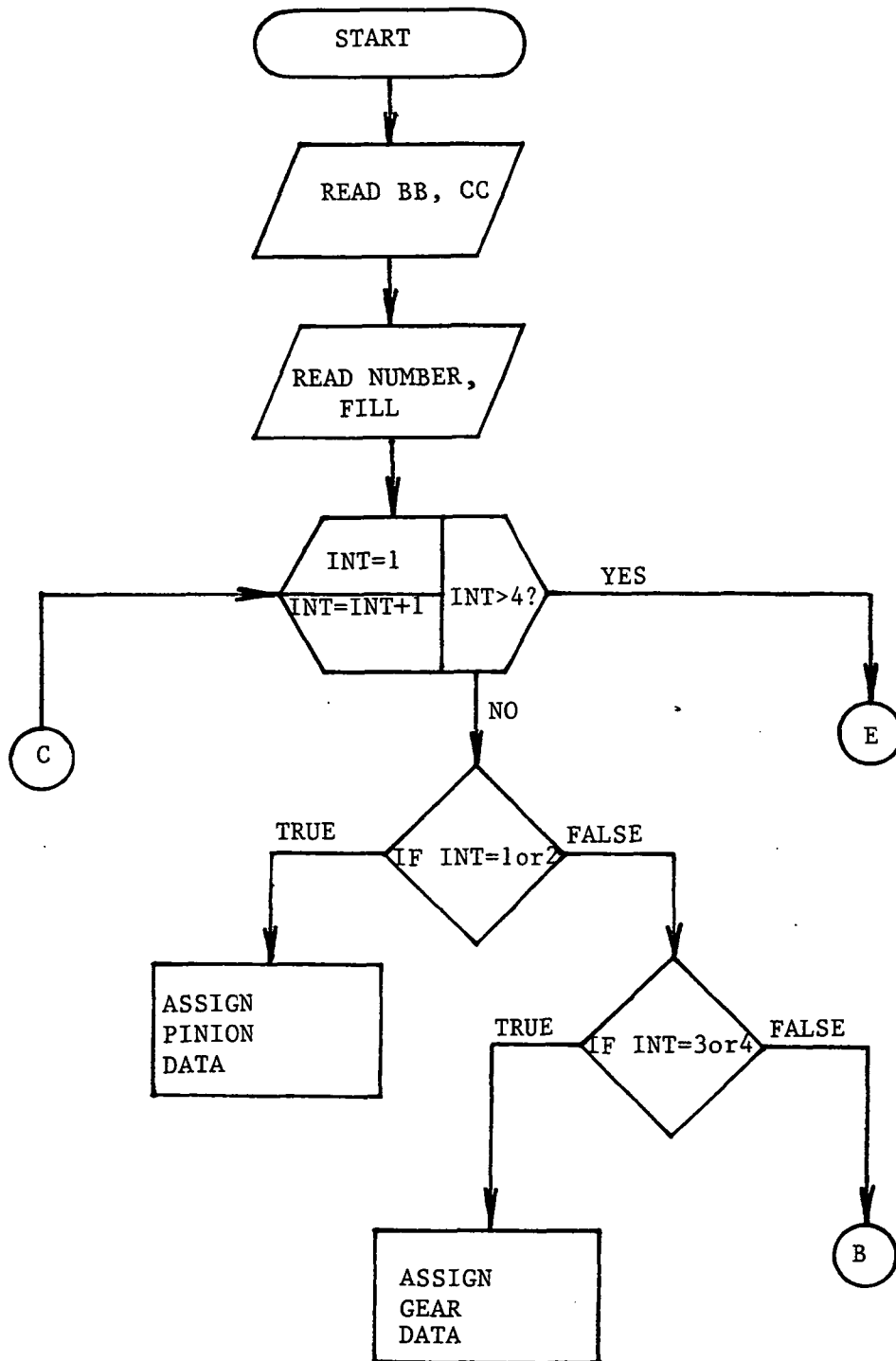
```

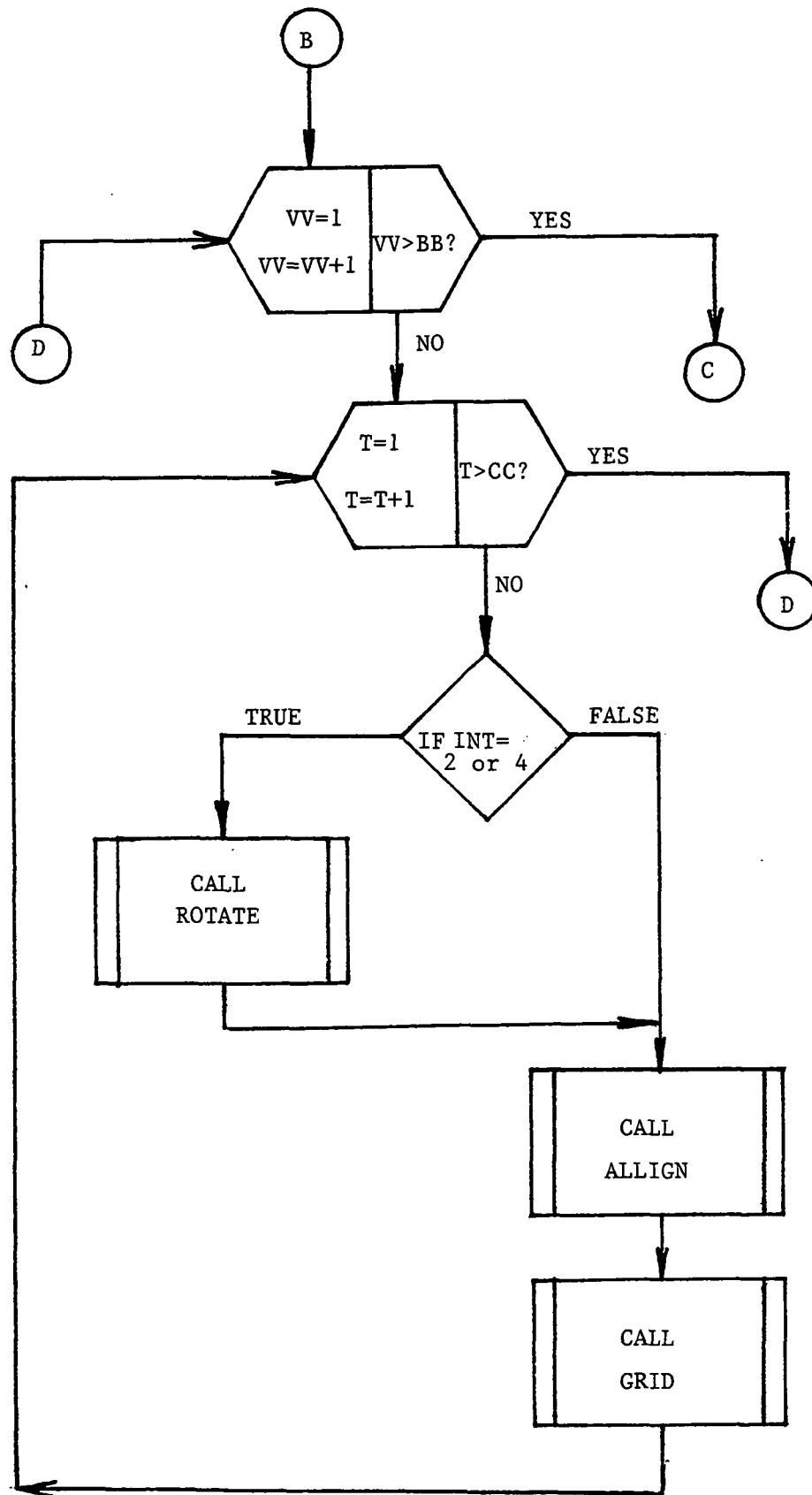
        write(nf1,918)'MESH,H',jj1,'T',jj2,',HEX,N,',fill,'/',
* numb,'/',fill,'/',numb,'/1'
        write(nf1,921)'MESH,H',jj2+1,'T',jj2+bb-1,',HEX,N,',
* numb,'/','3', '/',numb,'/','3', '/1'

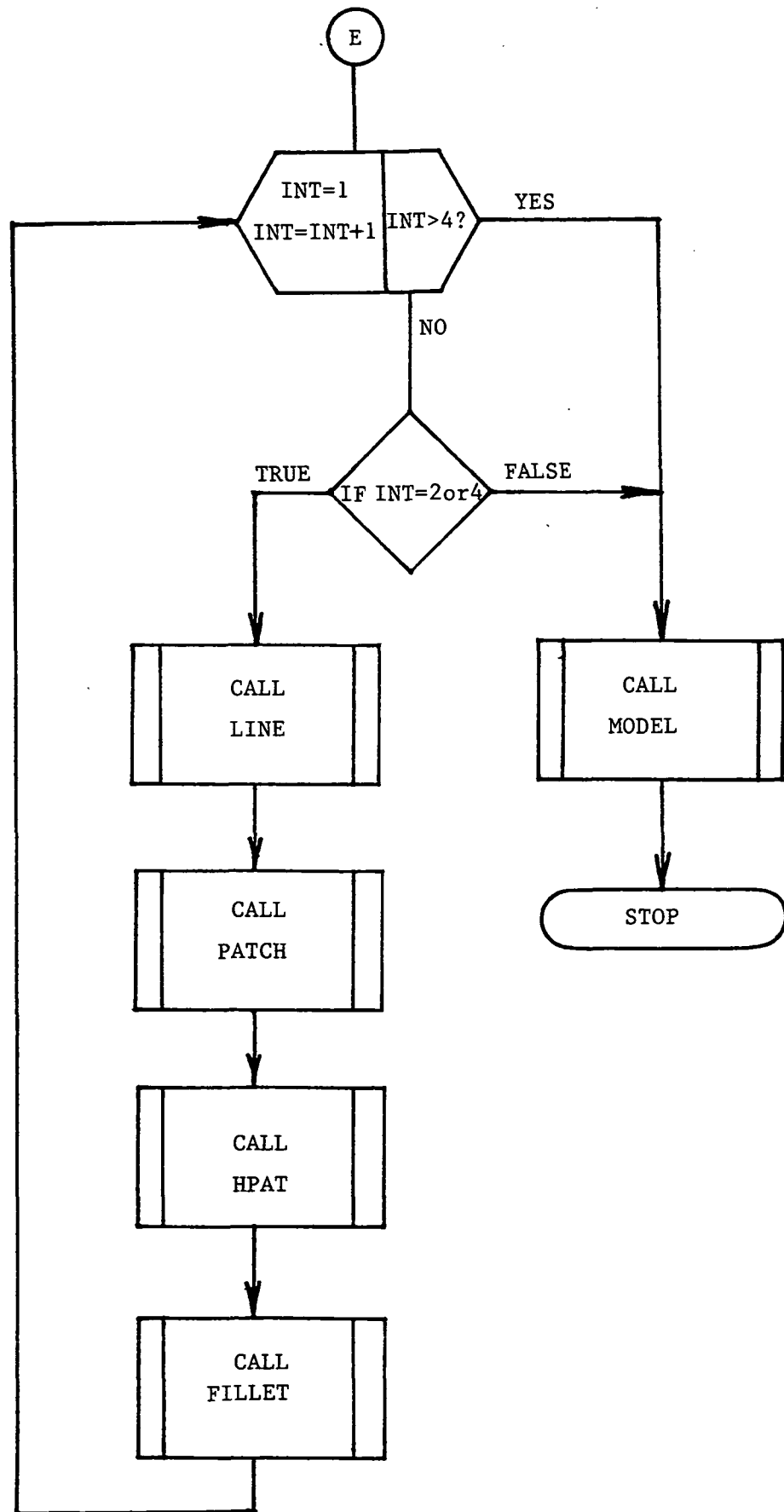
921      FORMAT(a6,i4,a1,i4,a7,i4,a1,a1,a1,i4,a1,a1,a2)
          K1 = (BB-1)*(cc-1) + 1
          K2 = 2*(BB-1)*(cc-1)
          L1 = 2*(bb-1)*cc + 1
          L2 = 2*(BB-1)*cc + 2*(bb-1)
C      to generate the whole pinion use this do loop
C      DO 902 J = 1,11
C          K = J + 1
C      WRITE(NF1,906)'NAME','PI',K,',','RO',',','3(0)/1/0/0/30,'
C      *      , 'PI',J
C 906      FORMAT(A6,A2,I2,A1,A2,A1,A14,A2,I2)
C 902      CONTINUE
C          WRITE(NF1,*)'NAME,PINION1'
C
          WRITE(NF1,*)'NAME,GEAR'
          WRITE(NF1,*)'GR,1T#,DEL'
          WRITE(NF1,*)'NAME,PINION,RO,4(0)/1/0/-90,PIN'
          write(nf1,*)'NAME,PINION,PL'
      Return
      END

```

FLOWCHART: PAT. F.







FLOWCHART: PAT.F (DISCUSSION)

There are four loops in the main program.

Loop 1: Loops one through four to read data for the four surfaces.

Loop 2: Loops one through BB, where BB is the number of points across the face of the tooth surface.

Loop 3: Loops one through CC, where CC is the number of points along the height of the tooth.

Loop 4: The final loop creates the lines, patches, hyper-patches, fillet and meshes the model for one gear tooth and one pinion tooth.

Subroutines:

1. ROTATE: Rotates the pinion and gear convex sides by Q degrees to create top land.
2. ALIGN: Aligns the pinion in mesh with the gear.
3. GRID: Creates PATRAN commands for the grids.
4. LINE: Creates PATRAN commands for the lines.
5. PATCH: Creates PATRAN commands for the patches.
6. HPAT: Creates PATRAN commands for the hyper-patches.
7. FILLET: Creates PATRAN commands to creat the fillet.
8. MODEL: Creates PATRAN commands to mesh the model.

REPORT DOCUMENTATION PAGE			Form Approved OMB No. 0704-0188	
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.				
1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE April 1994	3. REPORT TYPE AND DATES COVERED Final Contractor Report		
4. TITLE AND SUBTITLE Manual for Automatic Generation of Finite Element Models of Spiral Bevel Gears in Mesh		5. FUNDING NUMBERS WU-505-62-36 G-NAG3-1476 1L162211A47A		
6. AUTHOR(S) G.D. Bibel, S. Reddy, and A. Kumar				
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) University of North Dakota Grand Forks, North Dakota 58201		8. PERFORMING ORGANIZATION REPORT NUMBER E-8671		
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) Vehicle Propulsion Directorate U.S. Army Research Laboratory Cleveland, Ohio 44135-3191 and NASA Lewis Research Center Cleveland, Ohio 44135-3191		10. SPONSORING/MONITORING AGENCY REPORT NUMBER NASA CR-191009 ARL-CR-121		
11. SUPPLEMENTARY NOTES G.D. Bibel, University of North Dakota, Grand Forks, North Dakota (work funded by NASA Grant NAG3-1476); S. Reddy and A. Kumar, University of Akron, Akron, Ohio. Project Manager, Robert F. Handschuh, Army Research Laboratory, Vehicle Propulsion Directorate, organization code 2730, NASA Lewis Research Center, (216) 433-3969.				
12a. DISTRIBUTION/AVAILABILITY STATEMENT Unclassified - Unlimited Subject Category 37		12b. DISTRIBUTION CODE		
13. ABSTRACT (Maximum 200 words) The goal of this research is to develop computer programs that generate finite element models suitable for doing 3D contact analysis of faced milled spiral bevel gears in mesh. A pinion tooth and a gear tooth are created and put in mesh. There are two programs: Points.f and Pat.f to perform the analysis. Points.f is based on the equation of meshing for spiral bevel gears. It uses machine tool settings to solve for an N x M mesh of points on the four surfaces, pinion concave and convex, and gear concave and convex. Points.f creates the file POINTS.OUT, an ASCII file containing N x M points for each surface. (N is the number of node points along the length of the tooth, and M is nodes along the height.) Pat.f reads POINTS.OUT and creates the file t1.out. T1.out is a series of PATRAN input commands. In addition to the mesh density on the tooth face, additional user specified variables are the number of finite elements through the thickness, and the number of finite elements along the tooth full fillet. A full fillet is assumed to exist for both the pinion and gear.				
14. SUBJECT TERMS Gears; Gear teeth; Finite elements		15. NUMBER OF PAGES 58		16. PRICE CODE A04
17. SECURITY CLASSIFICATION OF REPORT Unclassified	18. SECURITY CLASSIFICATION OF THIS PAGE Unclassified	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT	